DEPARTMENT OF ECONOMICS,
MANAGEMENT AND STATISTICS

UNIVERSITY OF MILAN – BICOCCA

DEMS WORKING PAPER SERIES

In search of the Euro Area Fiscal Stance

Alice Albonico, Alessia Paccagnini, Patrizio Tirelli

No. 324 – January 2015

Dipartimento di Economia, Metodi Quantitativi e Strategie di Impresa
Università degli Studi di Milano - Bicocca
http://dems.unimib.it/

In search of the Euro Area Fiscal Stance*

Alice Albonico†
University of Milano Bicocca

Alessia Paccagnini‡
University College Dublin

Patrizio Tirelli§
University of Milano Bicocca

January 2016

Abstract

This paper investigates the role of fiscal and monetary policies over the aggregate EMU business cycle, with a specific focus on fiscal policies. We estimate large multipliers for public consumption and transfers. In spite of this, fiscal policies were substantantially muted. This result is confirmed even for the post 2007 period. In fact fiscal policies did not complement the monetary policy stimulus in response to the financial crisis. Further, we cannot detect any substantial aggregate effect of austerity measures implemented in peripheral countries. Finally, the post-2007 surge in expenditure-to-GDP ratios was apparently determined by non-policy shocks that reduced output growth.

Keywords: DSGE, Limited Asset Market Participation, Bayesian Estimation, Euro Area, Business Cycle, Monetary Policy, Fiscal Policy

JEL codes: C11, C13, C32, E21, E32, E37

*The paper is part of the RastaNews project funded by the European Community's 7^{th} Framework Programme (FP7). EC project 320278-RASTANEWS.

†Email: alice.albonico@unimib.it

‡Email: alessia.paccagnini@ucd.ie

§Email: patrizio.tirelli@unimib.it

1 Introduction

Following the apparent inability of monetary policies to avoid the recession that hit all advanced economies during the 2007 financial crisis, fiscal policies have been used to provide additional stimulus. The fiscal expansion was particularly large in the US and in the UK. By contrast, governments in the Euro area have been criticized for timid action in the 2007-2009 period (IMF, 2009) and for the "austerity" measures that were imposed onto peripheral countries after the beginning of the Greek crisis in 2010 (Cottarelli, 2012; Krugman, 2012; De Grauwe and Ji, 2013; Wolf, 2013; Stiglitz et al., 2014).

One specific feature of the Euro area is that national fiscal policies were constrained by the Stability and Growth Pact (SGP). According to Lane (2012) the Pact did not enforce sufficient discipline during the 1999-2007 period, characterized by a relatively favorable growth performance and by low cost for government finance. Then, after the onset of the Greek crisis in 2010, the SGP in its revised form imposed an unduly rapid fiscal correction in peripheral countries, accompanied by conservative fiscal stances in the rest of the area. This, in turn, caused an over-restrictive fiscal stance for the Euro area as a whole, that jeopardized the debt-reduction objective and left a legacy of higher than normal debt levels even in core countries. As a matter of fact, in 2014 the combination of persistently slow growth, high unemployment and declining inflation expectations induced the ECB to announce a large-scale asset purchase program, including purchases of sovereign bonds.

This paper investigates the role of fiscal and monetary policies over the aggregate EMU business cycle, with a specific focus on fiscal policies. The issue is important for at least two reasons. First, by looking at aggregate fiscal policies it is possible to understand the global implications of the Stability and Growth Pact, that was designed to impose a certain mix of discipline and discretion on individual countries. We shall therefore investigate the role played by fiscal feedbacks to business conditions and by discretionary actions, identified by shocks to fiscal variables. Second, over the next few years EMU policymakers will be confronted with the twofold task of reducing accumulated debt and, at the same time, of providing adequate stimulus to an economy that will be characterized by high unemployment and slow growth for several years to come. A correct assessment of fiscal multipliers and of the transmission channels associated to each fiscal instrument is therefore crucial to design fiscal policies that preserve macroeconomic stability for the Euro area as a whole. Achieving this goal should also facilitate the task of achieving fiscal adjustment in peripheral countries.

A vast literature, based on DSGE models, has analyzed the role of shocks and monetary policy in determining the EMU business cycle, starting from the seminal work of Smets and Wouters (2003, 2007; SW henceforth). Empirical evidence on fiscal policies is instead sparse. The relatively few models that incorporate analysis of fiscal policies extend the SW framework by introducing Limited Asset Market Participation, that is, a distinction between a fraction of households who are asset holders and smooth their consumption over the business cycle, and the remaining share of non-Ricardian households who do not participate in financial markets and entirely consume their current disposable income in each period. This allows to incorporate the possibility that public consumption shocks stimulate private consumption, as in Galí et al. (2007), and that transfers shocks provide a demand stimulus, as documented in Oh and Reis (2011). Coenen and Straub (2005, CS henceforth) investigate the effects of government spending shocks on aggregate consumption over the 1980-1999 period. Forni, Monteforte and Sessa (2009, FMS henceforth) focus on a slightly longer period, essentially restricted to the pre-crisis years. Both studies find that the share of non-Ricardian households is too small to establish a positive reaction of private consumption to public consumption shocks and therefore also assign a limited role to public transfers policies. Coenen, Straub and Trabandt (2012, 2013; CST henceforth) estimate their model over the 1985:1 to 2010:2 sample and focus on the role played by fiscal policies during the 2008-2009 recession period. They estimate a far smaller share of non-Ricardian households. They also show that this result is crucially determined by complementarity between private and public consumption in households preferences. As a consequence, Ricardian households raise their consumption in response to a public consumption increase. In this framework public transfers inevitably play an even more limited role than in CS and in FMS.

Relative to these studies, we differentiate our contribution in certain crucial aspects of the theoretical model and in the focus of the empirical analysis. First, instead of imposing that only Ricardian households preferences shape wage setting decisions, in our model wage-setting labor unions maximize an objective function that takes into account the marginal rate of substitution of all labor market participants, weighted by the shares of the two household types, as in Motta and Tirelli (2012, 2014). As shown in Motta and Tirelli (2013), this specification of the wage-setting mechanism has important implications for wage sensitivity to business cycle conditions. Therefore, excluding this effect here might well bias the results. Second, and more important, we do not account for complementarity between private and public consumption. By and large the analysis of aggregates may be misleading, because different components of public expenditures might exert opposite effects on private individual consumption decisions (Karras, 1994). For instance, Fiorito and Kollintzas (2004) show that in a panel of twelve European countries "public" goods (defense, security, judicial system expenditures) are substitutes for private spending, whereas complementarity arises for "merit" goods (expenditures for services also available in the market, such as health and education). Thus, to identify the effects of public consumption shocks one should consider separately the "merit" and the "public" goods.[1] Further, if one postulates that private and public consumption enter a CES utility bundle, then the weight associated to public consumption should be estimated along with the elasticity of substitution between the two goods. Unfortunately it is hard to identify these two parameters even in medium scale DSGE models (McGrattan, Rogerson and Wright, 1997; Cantore et al. 2014). In fact, CST calibrate the public consumption weight and consequently estimate a strong degree of complementarity. As shown in Ercolani and Valle e Azevedo (2014), fixing the weights in the utility bundle may bias the sign of the public consumption externality. Finally, the third distinctive feature of our model is that we are able to discuss the contribution of fiscal shocks to the Euro area business cycle during the EMU years including the post-2010 sovereign bond crisis.

Our results in a nutshell. Relative to CS, FMS and CST we obtain a much larger posterior

[1] Unfortunately disaggregate data are not available at the Euro-area level.

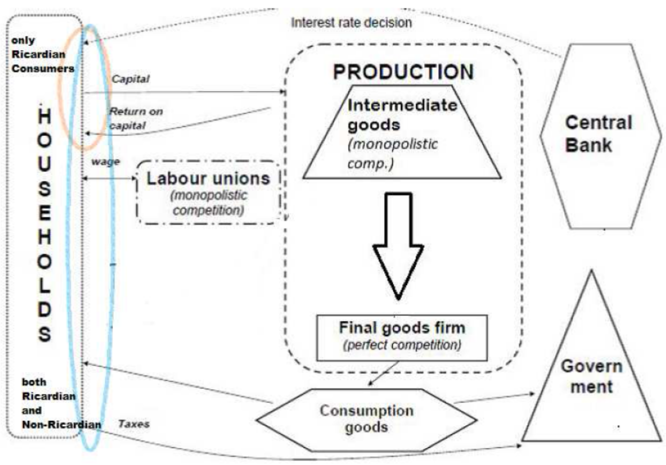
estimate for the share of non-Ricardian households, 53%. As a consequence, our estimates for public consumption and public transfer multipliers are also substantially larger. We could not identify a systematic reaction of tax rates and public expenditure variables to the Eurozone cyclical conditions. In other words, there seem to be no fiscal Taylor rules for the Eurozone as a whole. In this regard, our results are in line with FMS whereas CST obtain a significant feedback only for the labor tax variable. Historical output growth decomposition shows that fiscal shocks were substantially irrelevant before and after the financial crisis. Thus, our results convey the picture of a Euro area where the burden of implementing stabilization policies entirely falls on the European central Bank, whereas fiscal policies remain neutral in spite of their potentially important effects identified by the estimated multipliers. The post-2007 increase in the public-consumption-to-GDP ratio, typically regarded as an indicator of governments profligacy, was almost entirely determined by persistently adverse non-policy shocks. Looking ahead, our estimates suggest that fiscal consolidations based on public expenditure reductions (as advocated in Alesina and Ardagna, 2012) will cause during the transition a strong fall in consumption of non-Ricardian houeholds and, on average, an increase for asset holders.

In the remainder of the paper, Section 2 describes the model, Section 3 presents the results, and Section 4 concludes discussing policy implications.

2 The model

The structure of our model, described in Figure 1 is identical to SW (2005, 2007). Households supply capital services to monopolistic producers of intermediate goods and delegate wage setting decisions to monopolistic labor unions. At the given wage rate, labor is then supplied on demand to producers of intermediate goods. The final good is produced under perfect competition by assembling the intermediate inputs. The nominal interest rate and the fiscal policy decisions are respectively allocated to the Central Bank and to the Government. The model features standard nominal and real frictions, i.e. price and nominal wage stickiness, investment adjustment costs, variable capacity utilization, external consumption habits. As pointed out in the introduction we allow for the possibility of LAMP and distinguish between Ricardian and Non-Ricardian households. The technical Appendix provides a full description of the model. In what follows we focus on certain aspects of the model that are crucial to understand our results, i.e. characterization of preferences and shocks.

Figure 1: Model structure



There is a continuum of households indexed by $i \in [0,1]$. Their preferences are

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{1-\sigma} \left(\frac{c_t^i}{(c_{t-1})^b} \right)^{1-\sigma} \exp\left(\frac{(\sigma-1)}{1+\phi_l} (h_t)^{1+\phi_l} \right) \right\} \tag{1}$$

where $c_t^i = \frac{C_t^i}{z_t}$ and $c_t = \frac{C_t}{z_t}$ are individual and total real consumption levels normalized by a labour-augmenting non-stationary technology shifter z_t. The presence of z_t in 1 guarantees that the model has a balanced growth path when productivity is non stationary.[2] In contrast with CST (2012, 2013) we abstract from non-separability between private and public goods and stick to the utility function used in SW (2005, 2007), characterized by non separability between consumption and labor effort.[3] In fact our effort is to keep at a minimum the deviations from the SW model

[2]See Section 2.4 for more details.

[3]CST impose separability between consumption and labor effort.

which is a benchmark for the analysis of business cycle features. Our substantial deviation from SW is to incorporate the LAMP hypothesis. We assume that a fraction $1-\theta$ of households (Ricardian households, $i=o$) can access financial markets, own firms, trade government bonds, accumulate physical capital and rent capital services to firms. The remaining θ households (Non-Ricardian or LAMP households, $i=rt$) do not have access to financial markets and entirely consume their disposable income.

Parameter $0<b<1$ measures the degree of external habit in consumption. Differently from Smets and Wouters (2007) who use habits in differences, our specification here is based on habits in ratios. The specification chosen for characterizing consumption habits is inconsequential under the representative agent hypothesis (Dennis, 2009). This may not be the case here because individual wealth holdings and consumption levels differ across the two groups, both in steady state and in response to shocks. Carroll (2000) supports the alternative habits-in-ratio specification to avoid the risk of obtaining negative marginal utility of consumption. In the context of LAMP in DSGE models, Motta and Tirelli (2013) show that under the habits-in-difference specification indeterminacy may arise even for relatively small values of θ. By contrast, Menna and Tirelli (2014) show that indeterminacy is a lesser problem under the habit-in-ratio specification adopted in (1). In the context of an empirical LAMP model the habit-in-difference specification might bias obtained posteriors because the Dynare estimation routine forces estimates of the posterior distribution to be located in the determinacy region, i.e., it discards all posterior draws associated to indeterminacy and the current entry of the Monte Carlo Markov Chain (MCMC) is set at the previous draw.[4]

Parameter $\sigma>1$ is crucial to capture the standard effect of consumption habits, that is, to raise the marginal utility of consumption. In our empirical model $\sigma>1$ also implies complementarity between worked hours and consumption. Right from the outset, we emphasize that in our estimates no boundary will be imposed on the value of σ.

[4]In Section 3 below we compare our benchmark results under those obtained under the habits-in-difference specification.

Each household supplies the bundle of labor services $h_t^i = \left\{ \int_0^1 \left[h_t^i \left(j \right) \right]^{\frac{1}{1+\lambda_t^w}} dj \right\}^{1+\lambda_t^w}$. For each labor type j, the wage setting decision is allocated to a specific labor union. At the given nominal wage W_t^j, households supply the amount of labor that firms demand $h_t^j = \left(\frac{W_t^j}{W_t} \right)^{-\frac{1+\lambda_t^w}{\lambda_t^w}} h_t^d$, where $h_t^i = \int_0^1 h_t^j dj$ is the total labor demand. Demand for labor type j is split uniformly across the households, so that households supply an identical amount of labor services. Labor income is $W_t^i h_t^i = h_t^d \int_0^1 W_t^j \left(\frac{W_t^j}{W_t} \right)^{-\frac{1+\lambda_t^w}{\lambda_t^w}} dj$. Here, the parameter $\lambda_t^w < 1$ is inversely related to the intratemporal elasticity of substitution between the differentiated labour services supplied by the households, $\frac{1+\lambda_t^w}{\lambda_t^w}$. The parameter λ_t^w is assumed to follow an AR(1) process with i.i.d. Normal error term that is typically defined as a wage markup shock (SW, 2007).[5]

The flow budget constraint of Ricardian households is

$$\begin{aligned} &(1+\tau_t^c) P_t c_t^o + P_t I_t^o + \frac{B_{t+1}^o}{\varepsilon_t^b} = R_{t-1} B_t^o + \left(1 - \tau_t^l - \tau_t^{wh}\right) W_t h_t^o + P_t D_t^o + \\ &+ \left(1 - \tau_t^k\right) \left[R_t^k u_t^o - a\left(u_t^o\right) P_t \right] K_t^o + \tau_t^k \delta P_t K_t^o + P_t T R_t^o - P_t T_t^o \end{aligned} \tag{2}$$

were P_t is the consumption price index, I_t^o defines investment in physical capital, B_t^o are nominally riskless government bonds, D_t^o are firms profits, R_t is the nominal interest rate, W_t is the nominal wage rate index, K_t^o is the physical capital stock, u_t^o defines capacity utilization, R_t^k is the nominal rental rate of capital and $a\left(u_t^o\right)$ defines capacity utilization costs. Note that (7) accounts for tax rates levied on wage and capital incomes and on households consumption, τ_t^l, τ_t^k and τ_t^c respectively, for social contributions levied on labor incomes, τ^{wh}, for public transfers, TR_t^o, and for lump-sum taxes T_t^o. Term ε_t^b is a risk premium shock that affects the intertemporal margin, creating a wedge between the interest rate controlled by the central bank and the return on assets held by the households. It is assumed to follow a first-order autoregressive process with an i.i.d. Normal error term:

[5] We allow for simlar price markup shocks.

Capital stock dynamics are $K^o_{t+1} = (1-\delta) K^o_t + \varepsilon^i_t \left[1 - S\left(\frac{I^o_t}{I^o_{t-1}}\right)\right] I^o_t$, where δ is the depreciation rate and ε^i_t denotes an investment-specific technology shock that affects the real price of investment. It is assumed to evolve as an AR(1) process with i.i.d. Normal innovation term. The term $S\left(\frac{I^o_t}{I^o_{t-1}}\right)$ represents investment adjustment costs.

Non-Ricardian households consume their disposable labor income in each period:

$$(1+\tau^c) P_t C^{rt}_t = \left(1 - \tau^l_t - \tau^{wh}_t\right) W^{rt}_t h^{rt}_t + TR^{rt}_t \tag{3}$$

where TR^{rt}_t defines public transfers to non-Ricardian households.

Intermediate firms z are monopolistically competitive and use as inputs capital and labor services, $u^z_t K^z_t$ and h^z_t respectively. Firms are subject to a payroll tax, τ^{wf}_t when using the labor input. The production technology is:

$$Y^z_t = \varepsilon^a_t [u^z_t K^z_t]^\alpha [z_t h^z_t]^{1-\alpha} - z_t \Phi$$

where Φ are fixed production costs. ε^a_t defines a transitory total factor productivity shock, evolving as an AR(1) process with an i.i.d. Normal innovation term. The term z_t denotes a labor-augmenting technology process with permanent effects. We posit that $g_{z,t} = \left(\frac{z_t}{z_{t-1}}\right)$ also evolves as an AR(1) process around a deterministic trend.

2.1 Monetary and fiscal policy rules

Following CCW, the Central Bank sets the nominal interest rate according to a log-linear Taylor rule:

$$\begin{aligned} \hat{R}_t &= \phi_R \hat{R}_{t-1} + (1-\phi_R)\left[\widehat{\overline{\pi}}_t + \phi_\pi\left(\hat{\pi}_{t-1} - \widehat{\overline{\pi}}_t\right) + \phi_y \hat{y}_t\right] \\ &\quad + \phi_{\Delta\pi}\left(\hat{\pi}_t - \hat{\pi}_{t-1}\right) + \phi_{\Delta y}\left(\hat{y}_t - \hat{y}_{t-1}\right) + \hat{\varepsilon}^r_t \end{aligned} \tag{4}$$

where the hatted variables define log-deviations from steady state. In particular, $\hat{y}_t = \widehat{Y_t/z_t}$ is the log-deviation of observed output from the trend output level implied by the permanent technology component. Variable $\hat{y}_t$ is also interpreted as the output gap measure. ε_t^r is a monetary shock that follows a first-order autoregressive process with an i.i.d. Normal error term. Similarly to CST (2011, 2012), we assume a set of log-linear fiscal feedback rules such that

$$\hat{x}_t = \rho \hat{x}_{t-1} + \phi_{x,b} \hat{b}_{t-1} + \phi_{x,y} \hat{y}_t + \eta_t^x \tag{5}$$

where $\hat{x}_t = \hat{g}_t, \widehat{tr}_t, \hat{\tau}_t^l, \hat{\tau}_t^k, \hat{\tau}_t^c, \hat{\tau}_t^{wh}, \hat{\tau}_t^{wf}$; g_t is public consumption; η_t^x defines the fiscal policy shock. Our priors are such that $\phi_{x,b}$ and $\phi_{x,y}$ are strictly negative when $x = g, tr$ and strictly positive otherwise.

2.2 Bayesian estimation

After adjustment to obtain a balanced-growth equilibrium path, the model is log-linearized around its steady state and then estimated with Bayesian estimation techniques as in Smets and Wouters (2007), combining the priors of the parameters with the likelihood of the data.

Our observables are both macroeconomic and fiscal time series. For the macroeconomic variables, we include series from the AWM database (Fagan, Henry and Mestre, 2001, 13^{th} update, the data sample is 1985Q2-2012Q4): real GDP, private consumption, inflation, investments, compensation per employee, employment, and short-term nominal interest rate. Inflation has been calculated as the log difference in the GDP deflator. Output, consumption, investments, and wages are transformed in log differences; total employment has been detrended with a linear trend. For the fiscal sector, we include series from the new fiscal database by Parades et al. (2009):[6]

The fiscal series are:

[6] Capital tax rates could not be treated as observables because tax revenues from capital incomes are availabe only at annual frequency. We chose not to apply standard statistical tools to get quarterly data because the focus of the paper is to detect comovements between fiscal variables and output and public debt, and the aartificial generation of data at quarterly frequencies might in fact generate spurious correlations. Also note that in our estimated model we chose to switch off the capital tax rate feedbacks on output and public debt.

- real general government final consumption expenditure (GCR)
- nominal general government transfers to households (THN)
- nominal general government revenues from indirect taxes, total (TIN)
- nominal general government revenues from direct taxes, total (DTX)
- nominal general government revenues from employer social security contributions (SCR)
- nominal general government revenues from employee (and other, self-employed) social security contributions (SCE).

As discussed in CST, in the Parades et al. (2009) database social security contributions for employers and employee are only available after 1991Q1. Before that date, we have only the amount of the total social security contributions. We calculate the shares of employer and employee social security contributions on total social security contributions from 1991Q1 to 2012Q4. These shares are stable and as proposed in CST, we impose the average 1991Q1-2012Q4 shares to total social security contributions prior to 1991 to have two separate time series for employer and employee.

The nominal series are transformed in real series using the consumption deflator as implemented for the nominal macroeconomic variables. The consumption tax rate is calculated as a ratio, multiplied by 100, between the real consumption revenues (TIN/consumption deflator) and the amount of real consumption . The labor tax rate is calculated as a ratio, multiplied by 100, between the real labor revenues (DTX/consumption deflator) and the total amount of real wages. The two social securities rates are made as a ratio, multiplied by 100, between the real securities, respectively, for employer (SCR/consumption deflator) and for employee (SCE/consumption deflator), and the total amount of real wages. All the fiscal series are detrended using the HP filter.

Following CCW, the auxiliary equation

$$\hat{e}_t = \frac{\beta}{1+\beta} E_t \hat{e}_{t+1} + \frac{1}{1+\beta} \hat{e}_{t-1} + \frac{(1-\xi_e)(1-\beta\xi_e)}{(1+\beta)\,\xi_e} \left(\hat{h}_t - \hat{e}_t\right) \tag{6}$$

relates the employment variable, e_t, to the unobserved worked hours variable, h_t.[7]

To avoid stochastic singularity, we consider the same number of observables and shocks. Hence, we include thirteen structural shocks: transitory and permanent TFP shocks, risk premium shock, investment specific shock, interest rate shock, wage markup shock, price markup shock, government spending shock, transfer shock, consumption- labor- and payroll-tax shocks, and a shock to social security contributions.

The measurement equations for the seven macroeconomic variables are:

$$Y_t = \begin{bmatrix} \Delta \ln y_t \\ \Delta \ln c_t \\ \Delta \ln i_t \\ \Delta \ln w_t \\ \ln e_t \\ \Delta \ln P_t \\ \ln R_t^a \end{bmatrix} = \begin{bmatrix} \overline{\gamma} + \hat{g}_{z,t} \\ \overline{\gamma} + \hat{g}_{z,t} \\ \overline{\gamma} + \hat{g}_{z,t} \\ \overline{\gamma} + \hat{g}_{z,t} \\ \overline{e} \\ \overline{\pi}_* \\ \overline{r} \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} \\ \hat{c}_t - \hat{c}_{t-1} \\ \hat{\imath}_t - \hat{\imath}_{t-1} \\ \hat{w}_t - \hat{w}_{t-1} \\ \hat{e}_t \\ \hat{\pi}_t \\ \hat{r}_t \end{bmatrix}$$

where ln denotes 100 times log, $\Delta \ln$ refers to the log difference, $\overline{\gamma} = 100(g_z - 1)$ denotes a deterministic growth trend, common to the real variables GDP, consumption, investment and wages. Finally, $\overline{\pi}_* = 100(\overline{\pi} - 1)$ is the quarterly steady-state inflation rate, $\overline{r} = 100(\beta^{-1} g_z \overline{\pi} - 1)$ is the steady-state nominal interest rate, and $\overline{e}$ is the steady-state employment, normalized at zero.

When including the fiscal sector, we include the following measurement equation for government spending:

$$g_t^{obs} = \frac{y}{g} \hat{g}_t$$

where $\hat{g}_t = \frac{g_t - g}{y}$.[8] The tax rates observable variables are measured as deviation from HP-filter trend, thus their measurement equations are trivial.

[7]Parameter ξ_e determines the sensitivity of employment with respect to worked hours.

[8]A similar measurement equation is used for transfers.

2.3 Calibration and priors

A subset of parameters is calibrated (Table 1). The discount factor β is fixed at 0.99. The steady-state depreciation rate δ is 0.025, corresponding to a 10% depreciation rate per year. The capital share α is set at 0.3. Some parameters are drawn from CCW. The monetary authority's long-run (net) annualized inflation objective $\bar{\pi}-1$ is 1.9%, consistent with the ECB's quantitative definition of price stability. The steady state growth rate g_z is set at 2% in annual terms. The steady state net price markup is fixed at 35% while the steady state wage markup is set at 30%. Fixed costs in steady state are set so that steady state profits are zero.[9] The ratios of fiscal variables to GDP and the steady state tax rates are borrowed from Coenen et al. (2012). In particular, government spending to GDP ratio is fixed at 21.5%, in line with the sample average, and public-debt-to-GDP ratio is set at 60% in annual terms, in line with the Maastricht objective. Average sample values of government revenues/expenditures to GDP are taken as steady state values for fiscal variables (τ^c, τ^l, τ^k, τ^{wf}, τ^{wh}, G and T). We set the steady-state values of τ^c,τ^l, and τ^k, to 22.3%, to 11.6%, and 35%, respectively. Social security contributions and the payroll tax, τ^{wh} and τ^{wf}, are set to 12.7% and 23.2% respectively. Lump-sum taxes, paid by Ricardian households, allow to balance the budget in steady state. The steady state distribution of transfers is set to obtain a steady state consumption ratio between the two groups (c^{rt}/c^o) equal to 0.8.

The remaining parameters are estimated with Bayesian techniques. Priors, reported in Table 3, are set in line with empirical DSGE models of the Euro area (see CCW, and SW (2003, 2005)). In particular, parameters measuring the persistence of the shocks are Beta distributed, with mean 0.5 and standard deviation 0.1 and the standard errors of the innovations are assumed to follow an Inverse-gamma distribution. The parameters governing price and wage setting, habits, utilization elasticity, interest rate smoothing and the steady state fraction of LAMP are also Beta distributed. The fraction of LAMP θ is assumed to be Beta distributed with mean 0.3 and standard deviation 0.1[10]. The parameters of the Taylor are Normally distributed, whereas the parameter defining investment adjustment costs is Gamma distributed. Concerning the parameters characterizing the

[9] This implies that $(y+\Phi)/y = 1+\lambda^p$.

[10] We assume the prior of the fraction of LAMP as discussed in Albonico et al. (2014).

Table 1: Calibrated parameters

parameter	value
β	0.99
δ	0.025
α	0.3
α_p	6
λ_p	0.35
λ_w	0.3
$\bar{\pi} - 1$	0.0047
$g_z - 1$	0.005
$\frac{b}{y}$	2.4
$\frac{g}{y}$	0.215
τ^c	0.223
τ^l	0.116
τ^k	0.35
τ^{wh}	0.127
τ^{wf}	0.232

fiscal rules, the prior on feedback parameters is that they are Normally distributed with zero mean and a standard deviation of 2, in line with CST (2012). Given that there is not a clear evidence about the signs of these parameters for the Euro area, we opt for this less restrictive and diffuse prior.[11] It is important to highlight that unlike CST and in line with SW we do not impose any restriction on the parameters defining consumption and labor utility, σ and ϕ_l. Further, we posit that σ is Normally distributed with mean 1 and standard deviation 0.35, thus allowing for the possibility that $\sigma < 1$.

3 Results

Our estimates of the full model are quite disappointing. The global sensitivity tests implemented in Dynare (Ratto, 2008) show serious identification problems for some parameters, especially for

[11] Most papers are estimated for the US. For example, Zubairy (2014) uses Normally distributed feeback parameters on output for government spending and transfers, while imposes Gamma distributed coefficients for the feedback parameters on debt and on feeback parameters on output for capital and wage taxes. Leeper et al. (2010) uses only Gamma distributions for these parameters. Using a Normal distribution implies that we are not making any assumptions on the signs of the these parameters, similarly to Kliem and Kriwoluzky (2014).We experimented with the priors adopted by Zubairy and Leeper, but our reults did not change.

those of the fiscal sector. The problem persists even if we change shape (for example, an Inverse Gamma instead of a Normal) and parameters of the priors distributions. Further, the DSGE-VAR à la Del Negro and Schorfheide (2004) suggests the models is not well specified because the hyperparameter which represents the weight of the DSGE model restrictions is close to zero, implying that the DSGE model fails to explain the data.[12]For all the posteriors of the fiscal feedbacks $\phi_{x,b}$ and $\phi_{x,y}$ the Highest Posterior Density interval (HPD Int.) includes the zero value, and it is therefore impossible to obtain evidence of systematic fiscal policies at business cycle frequencies (see Table 2). The situation did not change when we estimated only subsets of the rules and alternative specifications for the statistical distributions of parameters that characterize feedbacks on debt and output.

The next step has been to estimate a restricted DSGE model where the fiscal feedbacks $\phi_{x,b}$ and $\phi_{x,y}$ have been removed altogether but the economy is assumed to react to fiscal shocks.[13] This restricted model is better specified than the model with fiscal reaction functions. Considering the DSGE-VAR à la Del Negro and Schorfheide (2004), we note a dramatic improvement in model ability to match the data. In fact the estimated hyperparameter is now around 0.95.[14] (see Table 3). For all parameters the marginal posterior distributions are unimodal, MCMC's convergence criteria are satisfied. Metropolis-Hastings convergence graphs suggest a fast and efficient convergence for all parameters.[15]

[12]The DSGE-VAR à la Del Negro and Schorfheide (2004) suggests the possible misspecification in structural models such as the DSGE. The estimated hybrid model, the DSGE-VAR, is a combination between restrictions from the economic model, and the statistical representation of the model, a VAR. The restrictions are "weighted" using a hyperparameter which evidences how much the DSGE model is misspecified. We implement the DSGE-VAR in Dynare imposing a prior on the hyperparameter as presented by Adjemian et al. (2008).

[13]In this case model stability obtains because the implicit lump-sum taxation ensures government solvency.

[14]In the DSGE-VAR à la Del Negro and Schorfheide (2004), when the hyperparameter is close to zero, it means we can use a reduced VAR, and the restrictions of the DSGE model does not count in the data. The selected DSGE model is misspecified to explain the data. When the hyperparameter is greater than zero, the grade of misspecification is decreasing. There is not a statistical rule to comment how much the model is more or less misspecified, it depends on several features such as the lag length and the shape of the marginal data density. For more technical details, see Del Negro et al. (2007) to an explanation of the DSGE-VAR in function of the model's marginal likelihood and lag length. In our empirical analysis, we estimate the DSGE-VAR with a different lag length, changing the prior for the hyperparameter, controlling the marginal likelihood in each exercise. The result is robust and the estimated hyperparameter is always close to 1.

[15]Visual diagnostics of the estimation results are available in the online Technical Appendix. The posterior distributions are computed considering 1,500,000 draws for 4 Markov chains, with 300,000 draws being discarded as burn-in draws. The average acceptance rate is roughly 28 percent.

The posterior for consumption utility ($\sigma = 2.091$, 90% HPD interval:1.709-2.474) is large relative to our prior and the lower boundary of the HPD interval is reassuringly larger than 1. This result implies that our estimated utility function is "well behaved", i.e. habits increase the marginal utility of consumption. Our estimated posterior for σ also implies complementarity between consumption and worked hours.

The posterior for the fraction of Non-Ricardian households is about 53% (HPD interval: 43%-62%). This fraction is much larger than the 18%, found in CST (2011, 2012) for the sample 1985:Q1 - 2010:Q2. By and large, the remaining posteriors are in line with previous studies.

As a robustness check, we estimate the model under the alternative habits in differences specification. In this case we obtain an even larger value for the share of non-Ricardian households ($\theta = 0.81$, HPD interval: 75%-88%), a smaller habit parameter ($b = 0.63$, HPD interval: 0.55-0.71) and a very small value for the consumption utility parameter ($\sigma = 0.32$, HPD interval: 0.20-0.44). This latter result would imply an implausibly large value for the intertemporal elasticity of substitution, at odds with a large body of empirical evidence (see Guvenen, 2006, and references cited therein). Furthermore, we noticed that the large elasticity of intertemporal substitution is crucial to avoid model indeterminacy, which occurs for $\sigma > 0.5$. This provides indirect support to our conjecture that under the habit-in-difference assumption results might be biased because estimates of the posterior distribution are forced into the determinacy region.

Table 2: Fiscal parameters

	Prior			Posterior		
parameters	Distribution	Mean	Std. Deviation	post. mean	90% HPD int.	
ϕ_{gb}	norm	0	2	-0.0001	-0.0005	0.0004
ϕ_{gy}	norm	0	2	0.0011	-0.0011	0.0034
ϕ_{trb}	norm	0	2	0.0001	-0.0005	0.0007
ϕ_{try}	norm	0	2	0.0004	-0.0027	0.0036
$\phi_{\tau lb}$	norm	0	2	0.0010	-0.0006	0.0026
$\phi_{\tau ly}$	norm	0	2	0.0068	-0.0023	0.016
$\phi_{\tau cb}$	norm	0	2	0.0025	0.0006	0.0045
$\phi_{\tau cy}$	norm	0	2	0.0077	-0.0017	0.0169
$\phi_{\tau wfb}$	norm	0	2	-0.0002	-0.0007	0.0002
$\phi_{\tau wfy}$	norm	0	2	-0.0029	-0.0055	-0.0004
$\phi_{\tau whb}$	norm	0	2	-0.0017	-0.0026	-0.0007
$\phi_{\tau why}$	norm	0	2	-0.0135	-0.0180	-0.0089

Table 3: Estimated parameters

	Prior distribution			Posterior distribution		
parameters	shape	mean	std dev	post. mean	90% HPD interval	
σ	norm	1	0.375	2.091	1.709	2.474
b	beta	0.7	0.1	0.883	0.808	0.961
ϕ_l	norm	2	0.75	2.729	1.703	3.770
θ	beta	0.3	0.1	0.531	0.438	0.625
γ_I	gamma	4	0.5	5.543	4.701	6.400
σ_u	beta	0.5	0.15	0.436	0.356	0.518
χ_p	beta	0.75	0.1	0.230	0.144	0.316
ξ_p	beta	0.75	0.1	0.898	0.896	0.900
χ_w	beta	0.75	0.1	0.724	0.559	0.891
ξ_w	beta	0.75	0.1	0.838	0.792	0.889
ξ_e	beta	0.5	0.15	0.838	0.822	0.853
ϕ_r	beta	0.9	0.05	0.910	0.870	0.948
ϕ_π	norm	1.7	0.1	1.790	1.660	1.913
ϕ_y	norm	0.12	0.05	0.078	0.034	0.120
$\phi_{\Delta y}$	norm	0.063	0.05	0.066	0.040	0.091
$\phi_{\Delta\pi}$	norm	0.3	0.1	0.189	0.126	0.251
ρ_a	beta	0.5	0.1	0.952	0.950	0.953
ρ_b	beta	0.5	0.1	0.910	0.880	0.941
ρ_i	beta	0.5	0.1	0.487	0.397	0.579
ρ_r	beta	0.5	0.1	0.728	0.602	0.854
ρ_{gz}	beta	0.5	0.1	0.455	0.349	0.561
ρ_p	beta	0.5	0.1	0.520	0.368	0.672
ρ_w	beta	0.5	0.1	0.850	0.799	0.900
ρ_g	beta	0.5	0.1	0.739	0.665	0.816
ρ_{tr}	beta	0.5	0.1	0.822	0.770	0.875
$\rho_{\tau c}$	beta	0.5	0.1	0.820	0.765	0.874
$\rho_{\tau l}$	beta	0.5	0.1	0.540	0.425	0.662
$\rho_{\tau wh}$	beta	0.5	0.1	0.767	0.699	0.833
$\rho_{\tau wf}$	beta	0.5	0.1	0.675	0.592	0.759
σ^a	invg	0.1	2	1.128	0.972	1.283
σ^b	invg	0.1	2	0.246	0.190	0.298
σ^i	invg	0.1	2	0.627	0.507	0.743
σ^r	invg	0.1	2	0.125	0.104	0.145
σ^{gz}	invg	0.1	2	0.948	0.806	1.088
σ^p	invg	0.1	2	0.123	0.086	0.158
σ^w	invg	0.1	2	0.163	0.115	0.210
σ^g	invg	0.1	2	0.075	0.066	0.083
σ^{tr}	invg	0.1	2	0.111	0.098	0.123
$\sigma^{\tau c}$	invg	0.1	2	0.229	0.203	0.254
$\sigma^{\tau l}$	invg	0.1	2	0.341	0.304	0.378
$\sigma^{\tau wh}$	invg	0.1	2	0.143	0.127	0.159
$\sigma^{\tau wf}$	invg	0.1	2	0.086	0.076	0.095
Log data density						-611.7

3.1 Fiscal multipliers

In this section we describe our fiscal multipliers in comparison with those obtained in CST and in FMS. Both in the short and in the long run[16] our estimated model predicts large public con-

[16] Short run and long run multipliers are defined as in Faia et al. (2013), the short run multiplier being the impact multiplier and the long run multiplier being the cumulative effect over the 40 periods considered.

sumption multipliers (Table 4), which are almost identical to CST. Their results are driven by the complementarity between private and government consumption. In our context the large effect of public consumption on output is mainly determined by the large share of non-Ricardian households who raise consumption in response to an increase in their labor incomes, in line with the theoretical mechanism identified in Galí et al. (2007). IRFs presented in Figure 2 show that the initial output variation has a negligible effect on inflation.[17] The ensuing small real interest rate increase and the positive effect of hours worked on the marginal utility of consumption limit the fall in consumption of Ricardian households. FMS obtain smaller multipliers and their model predicts a fall in aggregate consumption in response to the public consumption shock. This is mainly explained by the larger share of non-Ricardian household we estimate in our model and by the stronger inflation-output correlation estimated in their model, which elicits a monetary policy response that is more contractionary than in our model.

The public transfers multiplier is substantial in our model, whereas it is negligible in CST. This is easily explained by the larger share of non-Ricardian households we obtain in our estimates. Figure 3 shows that the positive response in the consumption of these households is reinforced by the surge in real wages and worked hours. This latter increase elicits an initially positive variation in consumption of Ricardian households, due to non-separability between consumption and labor effort and to the limited real interest rate increase.

The multiplier associated to consumption taxes is almost identical to CST, whereas we obtain a much larger multiplier for labor taxes and households social security contributions. The labor tax and social contributions multipliers obtained in FMS are closer to ours than to CST. Once more, the results are explained by the different role paid by LAMP. In fact, labor taxes and social security contributions mainly affect the supply side when the majority of consumers is represented by Ricardian households, whereas the contemporaneous variation in current disposable incomes becomes important when the size of non-Ricardians is relatively large. Further, non-separability

[17] In Figures 2 to 4, we plot the Bayesian IRFs obtained at the posterior mean (solid lines) and the 90% confidence bands (dotted lines). The standard deviations for each shock is the estimated standard deviation as shown in Table 3.

implies that the fall in hours worked has a depressing effect on Ricardian households' demand for consumption goods. By contrast, LAMP does not substantially change the output response to a consumption tax increase. When Ricardians dominate, the negative output multiplier is determined by households incentive to postpone consumption, whereas the fall in current disposable income is the key driver when LAMP is important.

Figure 4 present the IRFs in response to the labor tax rate shock. The tax rate increase has a contractionary effect on the economy, inflation decreases, thus also the nominal interest rate decreases, causing a real interest rate fall. This, in turn, triggers a positive response of investments. Our results unambiguouly show that the brunt of adjustment to the shock is borne by non-Ricardian households, who suffer from the sharp reduction in disposable income, whereas non-Ricardian households are able to smooth their consumption.

Summarizing, Table 4 allows to gauge the large re-distributive effect of public consumption and transfer shocks. In fact we estimate large cumulative positive responses in non-ricardian households consumption. In this regard, public transfer shocks turn out to have even stronger effects than public consumption shocks. Consumption multipliers for Ricardian households have opposite signs. Multipliers associated to the tax shock confirm that consumption of non-Ricardian households is more exposed to the shocks, but the tax shocks have some non-negligible long run effects even for Ricardian household.

Table 4: Fiscal multipliers. Tax rates multipliers are computed as a percentage increase in output or consumption following a 1 basis point increase in the tax rate.

	gov spending	transfers	consumption tax	labor tax	households ssc	firms ssc
			output			
short run	1.48	0.59	-0.48	-0.37	-0.34	0.09
long run	1.20	0.42	-0.41	-0.47	-0.37	-0.01
			aggregate consumption			
short run	0.45	0.85	-0.70	-0.53	-0.50	-0.04
long run	0.26	0.83	-0.74	-0.71	-0.60	-0.15
			Ricardians consumption			
short run	-0.04	-0.20	-0.28	-0.02	0.03	-0.02
long run	-0.76	-0.60	-0.18	-0.20	-0.07	-0.06
			LAMP consumption			
short run	0.97	1.98	-1.15	-1.09	-1.07	-0.07
long run	1.34	2.35	-1.34	-1.26	-1.17	-0.25

Figure 2: IRFs to a one standard deviation government spending shock.

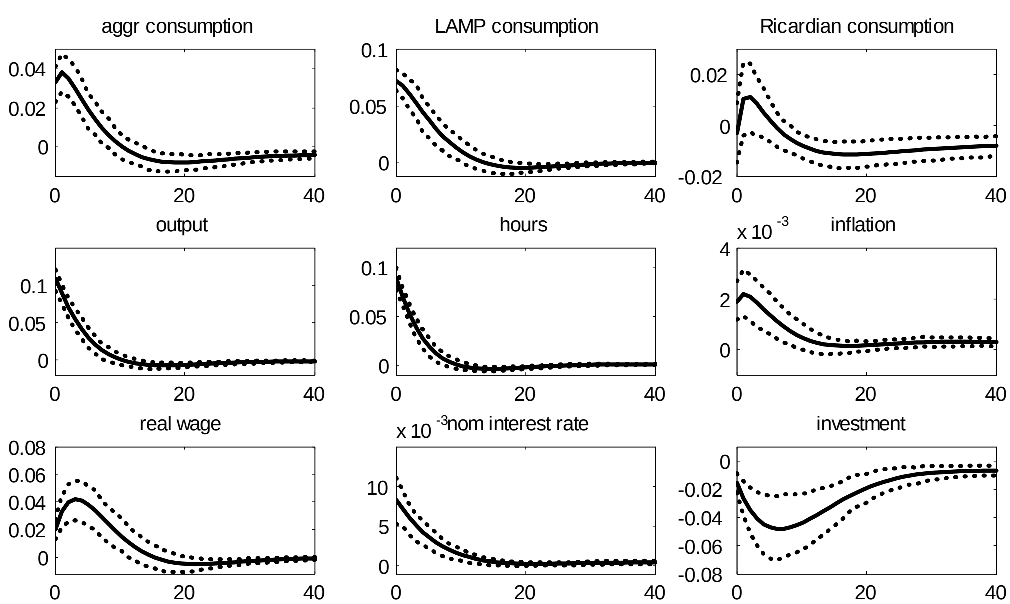


Figure 3: IRFs to a one standard deviation transfers shock.

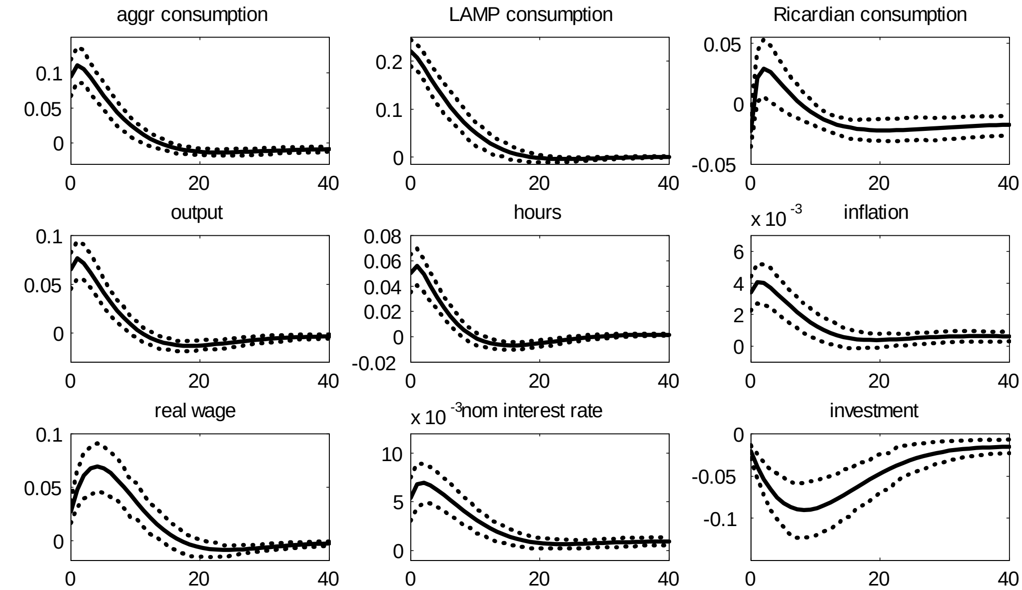
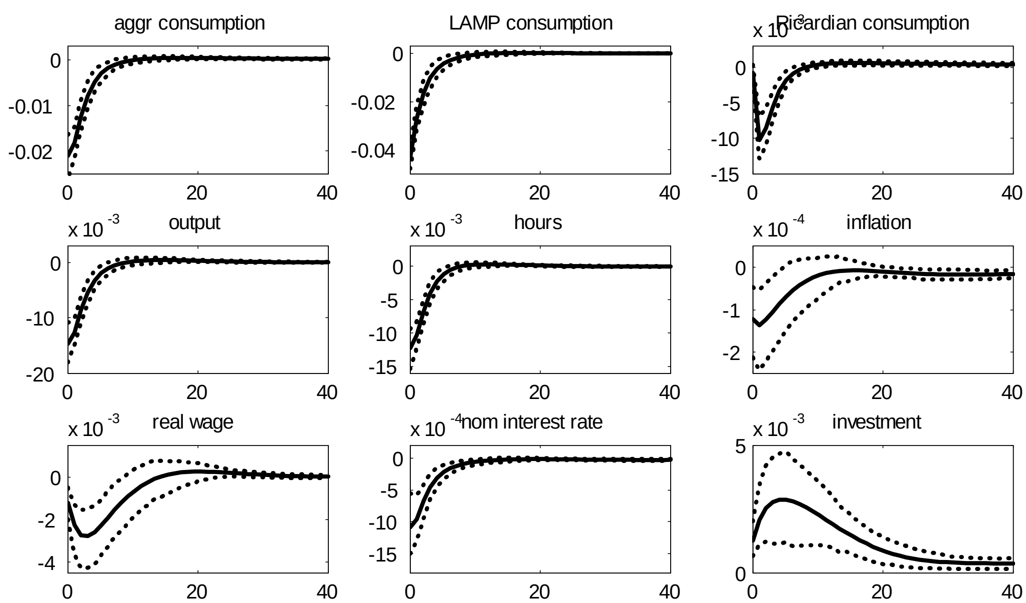


Figure 4: IRFs to a one standard deviation labor tax rate shock.



3.2 Variance and historical growth decompositions

Table 5 reports the variance decomposition for some key variables. The risk-premium and interest rate shocks cause about 56% of output growth volatility (62% for consumption growth). Shocks to the growth rate of productivity account for about 20% of output and consumption growth volatility. Technology shocks play a much larger role in determining volatilities of inflation and real wage growth. Wage markup shocks contribute to 18% of real wage growth volatility, but have a limited role otherwise. Price markup shocks play a minor role even on inflation. The most striking result is the irrelevance of fiscal shocks.[18] By contrast, note that monetary policy shocks provide the largest contribution to the volatility of consumption, output, and real wage growth. In addition, monetary policy shocks rank as the second largest contributor to inflation volatility.

The analysis of GDP growth historical decomposition allows to identify the specific contributions of policy and non-policy shocks (Figure 5). The 2008:1-2009:4 crisis was triggered by adverse productivity and investment-specific shocks,[19] whereas the post-2010 slowdown is associated to a sequence of adverse risk premium shocks in coincidence with the onset of the Greek crisis. Turning to policy shocks, note that monetary policy generated a sequence of negative stimuli that began in 2007, but then turned expansionary and contributed to the temporary recovery. As a matter of fact, the ECB interest rate on the main refinancing operations remained fixed at 4% until July 2008, when it was raised by 25 basis points. Interest rates in the Euro area started decreasing gradually only from October 2008. During the second contraction, we observe a persistent reversal of discretionary monetary policies, that turned contractionary once more.

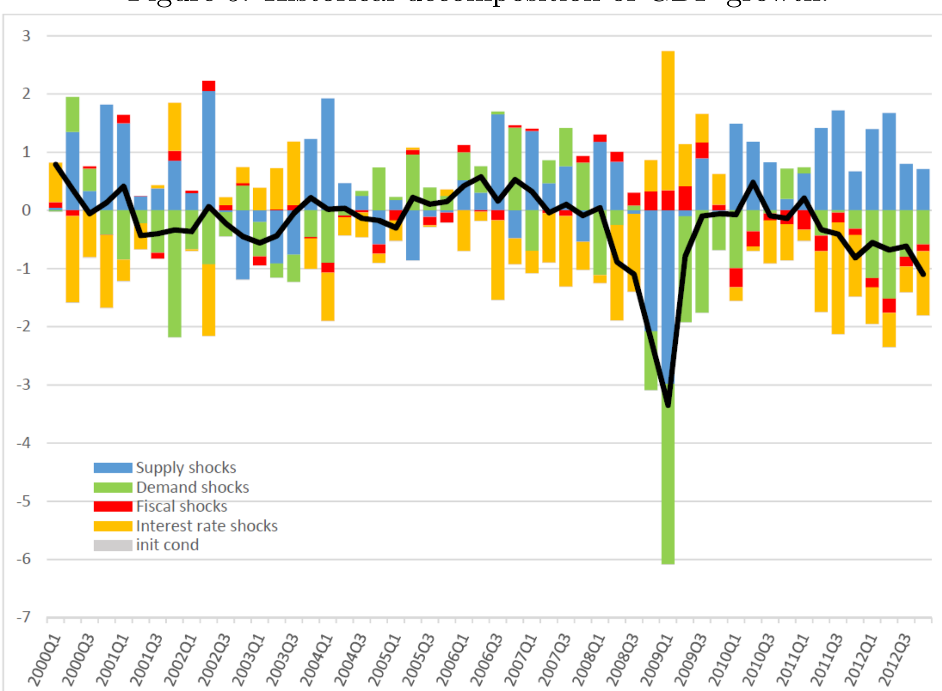
[18] FMS obtain an identical result over a different sample period (1980:1 to 2005:4) and under a different (restricted) composition of the Eurozone.

[19] The investment-specific shock might capture the effect of financial disintermediation on the the ability to turn savings into capital (Justiniano et al., 2011).

Table 5: Variance decomposition

	Δc	Δy	π	Δw	Δi	r
η^a	6.88	9.05	40.89	12.64	38.10	11.51
η^b	31.01	26.54	14.56	18.66	40.28	17.43
η^i	3.55	10.55	0.76	2.85	3.04	43.86
η^r	31.51	29.63	27.00	26.83	5.23	20.70
η^p	1.83	1.71	5.10	2.61	0.43	0.79
η^w	2.37	1.43	6.14	17.96	5.59	4.15
η^{g_z}	22.42	20.73	5.55	18.41	7.30	1.54
η^g	0.03	0.24	0.00	0.01	0.01	0.01
η^{tr}	0.02	0.00	0.00	0.00	0.00	0.00
$\eta^{\tau c}$	0.05	0.02	0.00	0.00	0.00	0.00
$\eta^{\tau l}$	0.01	0.00	0.00	0.00	0.00	0.00
$\eta^{\tau wh}$	0.00	0.00	0.00	0.00	0.00	0.00
$\eta^{\tau wf}$	0.00	0.00	0.00	0.00	0.00	0.00

Figure 5: Historical decomposition of GDP growth.



3.2.1 Fiscal policies during the financial and sovereign bond crises

The analysis of GDP growth historical decomposition confirms that it is difficult to identify episodes when fiscal shocks played an important role. Figure 6 shows that the admittedly marginal contribution of fiscal policies to output growth during the two crises was almost entirely determined by expenditure adjustments. Public consumption and transfers shocks were expansionary during the 2008 downturn. Then, after the onset of the Greek crisis we observe persistently contractionary shocks. Nevertheless, given the limited size of these shocks, the Eurozone fiscal stance was almost neutral during the whole crisis period, suggesting that the deterioration of the fiscal ratios was caused by the dismal output growth performance. This is confirmed by the historical decomposition of the Public-Consumption-to-GDP ratio (Figure 7).

Figure 6: Contribution of fiscal shocks to output growth.

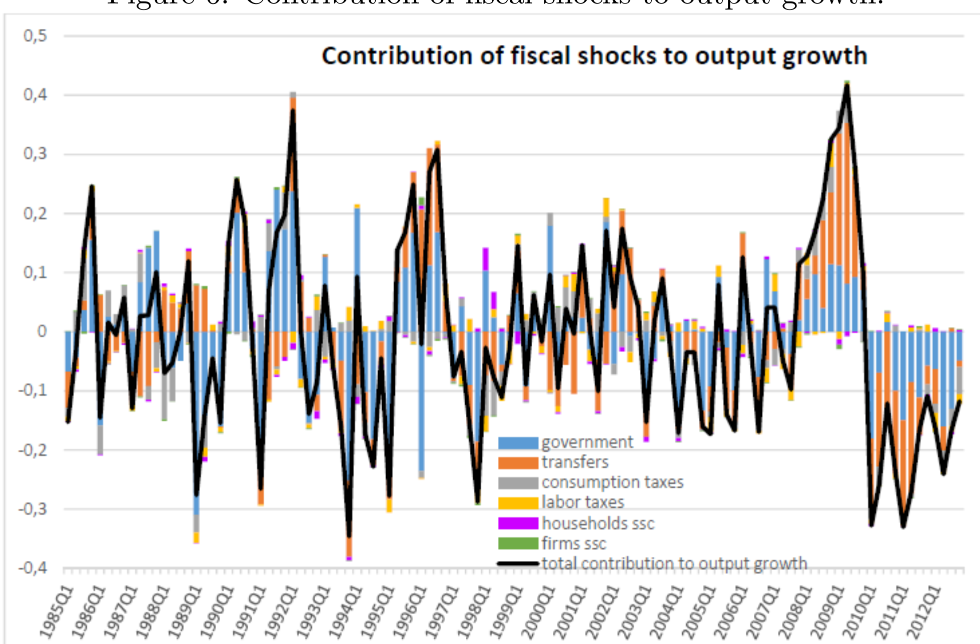
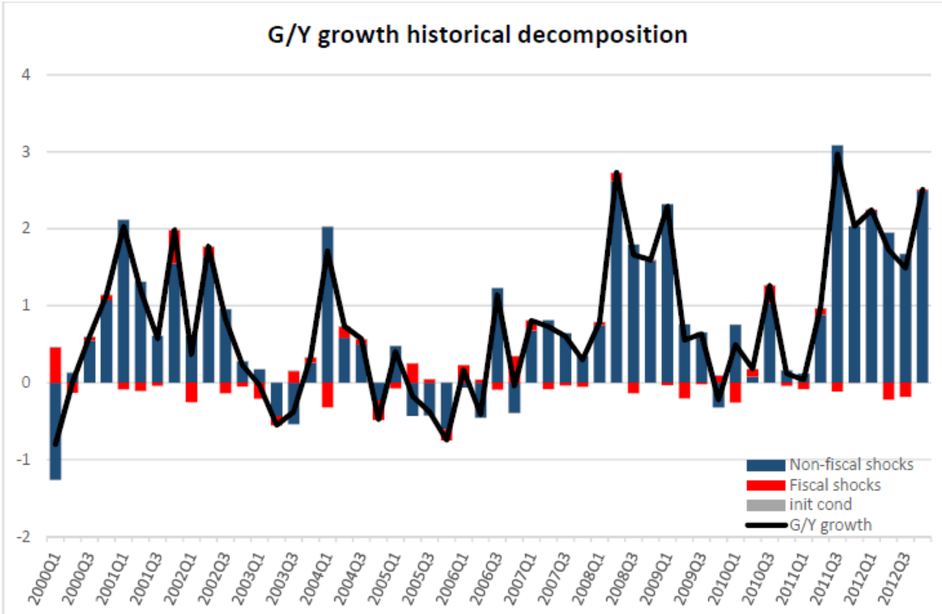


Figure 7: Historical decomposition of the growth rate of Public-Consumption-to-GDP ratio.



4 Conclusions

Our results convey a key message: aggregate fiscal policies played no role in determining the Euro area business cycle. The minimal contribution of fiscal shocks, i.e. the absence of discretionary fiscal policies, is consistent with the spirit of the SGP. To some extent, the apparent inability to detect fiscal feedbacks on output is also consistent with the view that the SGP should allow the working of automatic stabilizers in presence of asymmetric shocks (Buti and Franco, 2005), while stabilization of the Euro area business cycle should be sole responsibility of the ECB. Our findings about the post-2007 contribution of fiscal policies to output growth volatility are qualitatively consistent with conventional wisdom: expansionary stimulus was provided during 2008-2009 and the fiscal stance was reversed since 2010. However, given the minimal contribution of the aggregate fiscal shocks, our results suggest that, in contrast with the rest of OECD countries, monetary policy was the only tool used to fend off the 2008-2009 recession. In this regard, given the obvious asymmetry between EMU policies and the rest of OECD countries, Eurozone fiscal policies can be viewed as a missed opportunity. Further, we find that post-2010 austerity had a negligible aggregate impact: Eurozone stagnation and fading inflation expectations that induced the ECB to implement quantitative easing were caused by non-policy shocks.

Another important result is that the post-2007 rise in fiscal ratios was the consequence of such non-policy shocks that reduced output growth, whereas discretionary policies played no role in it. Given the large fiscal multipliers, this should sound a word of caution about the implementation of an aggregate fiscal consolidation before the Euro area has fully recovered. Finally, our estimates suggest that public expenditure contractions would strongly increase consumption inequality between asset-holders and non-Ricardian households. Thus, the fiscal policy mix should be carefully designed to deal with this problem. In this regard, our results provide strong empirical support to the theoretical work of Ferrara and Tirelli (2014) who show that combining public expenditure contractions with labor tax reductions and accommodative monetary policies limits the output contraction caused by a debt consolidation, also allowing to support incomes of those households who cannot exploit financial markets to smooth their consumption.

References

[1] Albonico A, Paccagnini A, Tirelli P, 2014. Estimating a DSGE model with Limited Asset Market Participation for the Euro Area, Working Papers 286, University of Milano-Bicocca, Department of Economics.

[2] Adjemian S, Darracq-Pariès M, Moyen S, 2008. Towards a Monetary Policy Evaluation Framework. ECB Working paper 942.

[3] Buti M, Franco D, 2005. Fiscal policy in Economic and Monetary Union: theory, evidence, and institutions. Edward Elgar Publishing.

[4] Calvo G.A., 1983. Staggered prices in a utility-maximizing framework, Journal of Monetary Economics, Elsevier, vol. 12(3), pages 383-398, September.

[5] Cantore C, Levine P, Melina G, Yang B, 2014. Deep versus Superficial Habit: It's All in the

Persistence. School of Economics Discussion Papers, 714.

[6] Carroll CD, 2000. Solving consumption models with multiplicative habits, Economics Letters, Elsevier, vol. 68(1), pages 67-77, July.

[7] Christiano LJ, Eichenbaum M, Evans CL, 2005. Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy, Journal of Political Economy, University of Chicago Press, vol. 113(1), pages 1-45, February.

[8] Christoffel K, Coenen G, Warne A, 2008. The New Area-Wide Model of the Euro area: a micro-founded open-economy model for forecasting and policy analysis, Working Paper Series 0944, European Central Bank.

[9] Coenen G, McAdam P, Straub R, 2008. Tax reform and labour-market performance in the Euro area: A simulation-based analysis using the New Area-Wide Model, Journal of Economic Dynamics and Control, Elsevier, vol. 32(8), pages 2543-2583, August.

[10] Coenen G, Straub R, 2005. Does Government Spending Crowd in Private Consumption? Theory and Empirical Evidence for the Euro Area, International Finance, Wiley Blackwell, vol. 8(3), pages 435-470, December.

[11] Coenen G, Straub R, Trabandt M, 2012. Fiscal Policy and the Great Recession in the Euro Area, American Economic Review, Papers & Proceedings, American Economic Association, vol. 102(3), pages 71-76, May.

[12] Coenen G., Straub R., Trabandt M., 2013. Gauging the effects of fiscal stimulus packages in the euro area, Journal of Economic Dynamics and Control, Elsevier, vol. 37(2), pages 367-386.

[13] Colciago A, 2011. Rule-of-thumb consumers meet sticky wages. Journal of Money, Credit and Banking 43, 325–353.

[14] Cottarelli C, 2012. Fiscal adjustment: Too much of a good thing?. VoxEU.org, 8.

[15] De Grauwe P, Ji Y, 2013. The legacy of austerity in the Eurozone. CEPS Commentary, 4.

[16] Del Negro M, Schorfheide F, 2004. Priors from General equilibrium Models for VARs, International Economic Review, 45, 643-673.

[17] Del Negro M, Schorfheide F, Smets F, Wouters R (2007) On the Fit of New-Keynesisan Models: Rejoinder, Journal of Business, Economics and Statistics, 25(2), 159-162.

[18] Dennis R, 2009. Consumption Habits in a New Keynesian Business Cycle Model, Journal of Money, Credit and Banking, Blackwell Publishing, vol. 41(5), pages 1015-1030, 08.

[19] Ercolani V, Valle e Azevedo J, 2014. The effects of public spending externalities, Journal of Economic Dynamics and Control, Elsevier, vol. 46(C), pages 173-199.

[20] Fagan G, Henry J, Mestre R, 2001. An area-wide model (AWM) for the Euro area, Working Paper Series 0042, European Central Bank.

[21] Faia E, Lechthaler W, Merkl C, 2013. Fiscal stimulus and labor market policies in Europe, Journal of Economic Dynamics and Control, Elsevier, vol. 37(3), pages 483-499.

[22] Ferrara, M., and Tirelli, P., Fiscal Consolidations: Can We Reap the Gain and Escape the Pain? 2014. University of Milan Bicocca Department of Economics, Management and Statistics Working Paper No. 283. Available at SSRN: http://ssrn.com/abstract=2509715 or http://dx.doi.org/10.2139/ssrn.2509715

[23] Ferrara, M., and Tirelli, P., 2015. Limited Asset Market Participation and Macro-dynamics in Medium-scale DSGE models. A perspective for the Eurozone, *mimeo.*

[24] Fiorito R, Kollintzas T, 2004. Public goods, merit goods, and the relation between private and government consumption, European Economic Review, Elsevier, vol. 48(6), pages 1367-1398, December.

[25] Forni L, Monteforte L, Sessa L, 2009. The general equilibrium effects of fiscal policy: Estimates for the Euro area, Journal of Public Economics, vol. 93(3-4), pages 559-585.

[26] Galí J, López-Salido D, Vallés J, 2007. Understanding the effects of government spending on consumption, Journal of the European Economic Association 5 (1), 227–270.

[27] Guvenen F, 2006. Reconciling conflicting evidence on the elasticity of intertemporal substitution: A macroeconomic perspective, Journal of Monetary Economics, 53(7), 1451-1472

[28] IMF, 2009. IMF Group of Twenty meeting of the ministers and central bank governors March 13–14, 2009 London, U.K. Global Economic Policies and Prospects.

[29] Karras G, 1994. Government Spending and Private Consumption: Some International Evidence, Journal of Money, Credit and Banking, Blackwell Publishing, vol. 26(1), pages 9-22, February.

[30] Kimball MS, 1995. The Quantitative Analytics of the Basic Neomonetarist Model, Journal of Money, Credit and Banking, Blackwell Publishing, vol. 27(4), pages 1241-77, November.

[31] Kliem M, Kriwoluzky A, 2014. Toward a Taylor Rule for Fiscal Policy, Review of Economic Dynamics, Elsevier for the Society for Economic Dynamics, vol. 17(2), pages 294-302, April.

[32] Krugman P, 2012. Europe's austerity madness, New York Times, 28, A35.

[33] Justiniano A, Primiceri G, Tambalotti A, 2011. Investment Shocks and the Relative Price of Investment Review of Economic Dynamics, Elsevier for the Society for Economic Dynamics, vol. 14(1), pages 101-121, January.

[34] Lane PR, 2012. The European sovereign debt crisis, The Journal of Economic Perspectives, 26(3), 49-67.

[35] Leeper EM, Plante M, Traum N, 2010. Dynamics of fiscal financing in the United States, Journal of Econometrics, Elsevier, vol. 156(2), pages 304-321, June.

[36] McGrattan, E. R., Rogerson, R., & Wright, R. 1997. An equilibrium model of the business cycle with household production and fiscal policy. International Economic Review, 267-290.

[37] Menna L, Tirelli P, 2014. The Equity Premium in a DSGE Model with Limited Asset Market Participation, mimeo.

[38] Motta G, Tirelli P, 2012. Optimal Simple Monetary and Fiscal Rules under Limited Asset

Market Participation, Journal of Money, Credit and Banking, Blackwell Publishing, vol. 44(7), pages 1351-1374, October.

[39] Motta G, Tirelli P, 2013. Limited Asset Market Participation, Income Inequality and Macroeconomic Volatility, Working Papers 261, University of Milano-Bicocca, Department of Economics, Dec 2013.

[40] Motta G, Tirelli P, 2014. Money Targeting, Heterogeneous Agents, and Dynamic Instability, Macroeconomic Dynamics, available on CJO2014. doi:10.1017/S1365100513000394.

[41] Oh H, Reis R, 2011. Targeted Transfers and the Fiscal Response to the Great Recession, NBER Working Papers 16775.

[42] Paredes J, Pedregal DJ, Perez J, 2009. A Quarterly Fiscal Database for the Euro Area Based on Intra-Annual Fiscal Information, ECB Working Paper No. 1132, European Central Bank, September.

[43] Ratto M, 2008. Analysing DSGE Models with Global Sensitivity Analysis, Computational Economics, Society for Computational Economics, vol. 31(2), pages 115-139, March.

[44] Smets F, Wouters R, 2003. An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area, Journal of the European Economic Association, MIT Press, vol. 1(5), pp. 1123-1175.

[45] Smets F, Wouters R, 2007. Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach, American Economic Review, American Economic Association, vol. 97(3), pp. 586-606.

[46] Stiglitz JE, Fitoussi JP, Bofinger P, Esping-Andersen G, Galbraith JK, Grabel I, 2014. A Call for Policy Change in Europe, Challenge, 57(4), 5-17.

[47] Wolf M, 2013. How austerity has failed. New York Review of Books, 11.

[48] Zubairy S, 2014. On Fiscal Multipliers: Estimates From A Medium Scale Dsge Model, International Economic Review, Department of Economics, University of Pennsylvania and

Osaka University Institute of Social and Economic Research Association, vol. 55, pages 169-195, 02.

5 Technical Appendix

5.1 The model

5.1.1 Ricardian households FOCs

The flow budget constraint of Ricardian households is

$$\begin{aligned}(1+\tau_t^c)\,P_t c_t^o + P_t I_t^o + \frac{B_{t+1}^o}{\varepsilon_t^b} &= R_{t-1}B_t^o + \left(1-\tau_t^l-\tau_t^{wh}\right)W_t h_t^o + P_t D_t^o + \\ &+ \left(1-\tau_t^k\right)\left[R_t^k u_t^o - a\left(u_t^o\right)P_t\right]K_t^o + \tau_t^k \delta P_t K_t^o + P_t TR_t^o - P_t T_t^o\end{aligned} \tag{7}$$

were P_t is the consumption price index, I_t^o defines investment in physical capital, B_t^o are nominally riskless government bonds, D_t^o are firms profits, R_t is the nominal interest rate, K_t^o is the physical capital stock, u_t^o defines capacity utilization and R_t^k is the nominal rental rate of capital. Note that (7) accounts for tax rates levied on wage and capital incomes and on households consumption, τ_t^l, τ_t^k and τ_t^c respectively, for social contributions levied on labor incomes, τ^{wh}, for public transfers, TR_t^o, and for lump-sum taxes T_t^o. Term ε_t^b is a risk premium shock that affects the intertemporal margin, creating a wedge between the interest rate controlled by the central bank and the return on assets held by the households. It is assumed to follow a first-order autoregressive process with an i.i.d. Normal error term:

$$\log\left(\varepsilon_t^b\right) = (1-\rho_b)\log\left(\varepsilon^b\right) + \rho_b \log\left(\varepsilon_{t-1}^b\right) + \eta_t^b$$

Capital stock dynamics are as follows:

$$K_{t+1}^o = (1-\delta)\,K_t^o + \varepsilon_t^i\left[1 - S\left(\frac{I_t^o}{I_{t-1}^o}\right)\right]I_t^o \tag{8}$$

where δ is the depreciation rate and ε_t^i denotes an investment-specific technology shock that affects the real price of investment. It is assumed to evolve as an AR(1) process with i.i.d. Normal innovation term: $\log\left(\varepsilon_t^i\right) = (1-\rho_i)\log\left(\varepsilon^i\right) + \rho_i \log\left(\varepsilon_{t-1}^i\right) + \eta_t^i$.

The term $S\left(\frac{I_t^o}{I_{t-1}^o}\right)$ represents investment adjustment costs. In line with Christoffel et al. (2008, CCW henceforth), the adjustment costs function is:

$$S\left(\frac{I_t^o}{I_{t-1}^o}\right) = \frac{\gamma_I}{2}\left(\frac{I_t^o}{I_{t-1}^o} - g_z\right)^2 \tag{9}$$

where g_z is the steady state trend growth rate of the economy. The intensity of utilizing physical capital is subject to a proportional cost, as in Christiano et al. (2005):

$$a\left(u_t^o\right) = \gamma_{u1}\left(u_t^o - 1\right) + \frac{\gamma_{u2}}{2}\left(u_t^o - 1\right)^2 \tag{10}$$

Ricardian households maximize (1) with respect to C_t^o, B_{t+1}, I_t^o, K_{t+1}^o, u_t^o, subject to (7), (8), (9) and (10). The first order conditions are:

$$\frac{\left(c_t^o\right)^{-\sigma}\left(c_{t-1}\right)^{b(\sigma-1)}\exp\left(\frac{(\sigma-1)}{1+\phi_l}\left(h_t^o\right)^{1+\phi_l}\right)\frac{1}{z_t}}{\left(1+\tau_t^c\right)} = \Lambda_t^o / P_t \tag{11}$$

$$R_t = \pi_{t+1}\frac{\Lambda_t^o}{\beta\varepsilon_t^b\Lambda_{t+1}^o} \tag{12}$$

$$\begin{aligned} 1 \quad = \quad & Q_t^o\varepsilon_t^i\left\{1 - \gamma_I\left(\frac{I_t^o}{I_{t-1}^o} - g_z\right)\frac{I_t^o}{I_{t-1}^o} - \frac{\gamma_I}{2}\left(\frac{I_t^o}{I_{t-1}^o} - g_z\right)^2\right\} \\ & + \frac{\Lambda_{t+1}^o}{\Lambda_t^o}Q_{t+1}^o\varepsilon_{t+1}^i\beta\gamma_I\left(\frac{I_{t+1}^o}{I_t^o} - g_z\right)\left(\frac{I_{t+1}^o}{I_t^o}\right)^2 \end{aligned} \tag{13}$$

$$\frac{\Lambda_{t+1}^o}{\Lambda_t^o}\beta\left\{\left(1-\tau_t^k\right)\left[\frac{R_{t+1}^k}{P_{t+1}}u_{t+1}^o - a\left(u_{t+1}^o\right)\right] + \tau_t^k\delta + Q_{t+1}^o\left(1-\delta\right)\right\} = Q_t^o \tag{14}$$

$$\frac{R_t^k}{P_t} = \gamma_{u1} + \gamma_{u2}\left(u_t - 1\right) \tag{15}$$

where Λ_t^o/P_t and $\Lambda_t^o Q_t^o$ are the Lagrange multipliers associated respectively with (7) and (8). Note that in (11) the consumption tax drives a wedge between the marginal utility of consumption and the marginal utility of wealth, Λ_t^o/P_t. We define $\pi_t = \frac{P_t}{P_{t-1}}$ as the gross rate of inflation. Equation (12) is the Euler equation. Q_t^o is the shadow price of a unit of investment good. Equations (13) and (14) are the first order conditions for investment and capital respectively. Equation (15) identifies the optimal degree of capital utilization.

5.1.2 Non-Ricardian households

LAMP households consume their disposable labor income in each period:

$$\left(1+\tau^c\right) P_t C_t^{rt} = \left(1-\tau_t^l-\tau_t^{wh}\right) W_t^{rt} h_t^{rt} + TR_t^{rt} \tag{16}$$

where TR_t^{rt} defines public transfers to non-Ricardian households.

5.1.3 Wage setting

Nominal wages setting is based on the Calvo formalism. In each period, union j optimally chooses the nominal wage with probability $(1-\xi_w)$. Non-optimizing unions adopt the following indexation scheme (SW, 2007):

$$W_t^j = g_{z,t}\pi_{t-1}^{\chi_w}\bar{\pi}_t^{(1-\chi_w)}W_{t-1}^j$$

where $\bar{\pi}_t$ is the exogenous trend inflation rate.

We assume that the representative union objective function is a weighted average $(1-\theta,\, \theta)$ of the two households types' utility functions, as in Colciago (2011). The union problem therefore is:

$$\max_{\tilde{W}_t^j} E_t \sum_{s=0}^{\infty} (\xi_w\beta)^s \left\{ \begin{array}{c} \frac{1-\theta}{1-\sigma}\left(\frac{c_{t+s}^o}{(c_{t+s-1})^b}\right)^{1-\sigma} \exp\left(\frac{(\sigma-1)}{1+\phi_l}\left(h_{t+s}^o\right)^{1+\phi_l}\right) \\ +\frac{\theta}{1-\sigma}\left(\frac{c_{t+s}^{rt}}{(c_{t+s-1})^b}\right)^{1-\sigma} \exp\left(\frac{(\sigma-1)}{1+\phi_l}\left(h_{t+s}^{rt}\right)^{1+\phi_l}\right) \end{array} \right\} \tag{17}$$

subject to (**??**), (7) and (16).

Condition (17) establishes an importance difference with respect to previous empirical DSGE models that account for LAMP (Coenen and Straub, 2005; CST, 2012, 2013), but assume that Non-Ricardian households preferences cannot affect wage-setting decisions. Our assumption that unions take into account the interests of Non-Ricardian households implies a potentially quite different path for wage dynamics whenever the two household groups make different consumption choices in response to shocks, as shown in Motta and Tirelli (2013).

The representative union FOC is:

$$
\begin{aligned}
0 \;=\; & E_t \sum_{s=0}^{\infty} (\xi_w \beta)^s \left(c_{t+s-1}\right)^{b(\sigma-1)} \exp\left(\frac{(\sigma-1)}{1+\phi_l}\left(h_{t+s}\right)^{1+\phi_l}\right) h^j_{t+s} \cdot \\
& \cdot \left\{ \begin{array}{c} \tilde{W}^j_t \frac{\left(1-\tau^l_{t+s}-\tau^{wh}_{t+s}\right) g_{z,t,t+s} \pi^{\chi_w}_{t,t+s-1} \bar{\pi}^{1-\chi_w}_{t,t+s}}{\left(1+\tau^c_{t+s}\right) P_{t+s} z_{t+s}} \left(1-\frac{1+\lambda^w_{t+s}}{\lambda^w_{t+s}}\right) \left[(1-\theta)\left(c^o_{t+s}\right)^{-\sigma} + \theta\left(c^{rt}_{t+s}\right)^{-\sigma}\right] \\ +\frac{1+\lambda^w_{t+s}}{\lambda^w_{t+s}} \left[(1-\theta)\left(c^o_{t+s}\right)^{-\sigma} MRS^o_{t+s} + \theta\left(c^{rt}_{t+s}\right)^{-\sigma} MRS^{rt}_{t+s}\right] \end{array} \right\}
\end{aligned}
$$

where:

$$
\pi_{t,t+s-1} = \begin{cases} 1 & \text{for } s=0 \\ \pi_t \cdot \pi_{t+1} \cdot \ldots \cdot \pi_{t+s-1} & \text{for } s=1,2.... \end{cases}
$$

$$
\bar{\pi}_{t,t+s} = \begin{cases} 1 & \text{for } s=0 \\ \bar{\pi}_t \cdot \bar{\pi}_{t+1} \cdot \ldots \cdot \bar{\pi}_{t+s} & \text{for } s=1,2.... \end{cases}
$$

$$
MRS^o_t = -\frac{U^o_h\left(c^o_t, h^o_t\right)}{U^o_c\left(c^o_t, h^o_t\right)} = c^o_t \left(h^o_t\right)^{\phi_l}
$$

$$
MRS^{rt}_t = -\frac{U^{rt}_h\left(c^{rt}_t, h^{rt}_t\right)}{U^{rt}_c\left(c^{rt}_t, h^{rt}_t\right)} = c^{rt}_t \left(h^{rt}_t\right)^{\phi_l}
$$

and $g_{z,t,t+s} = \prod_{s=1}^{s} g_{z,t+s}$.

5.1.4 Firms

Final good firms The final good Y_t is produced under perfect competition. A continuum of intermediate inputs $Y_t(z)$ is combined as in Kimball (1995). The final good producers maximize profits:

$$\max_{Y_t, Y_t^z} P_t Y_t - \int_0^1 P_t^z Y_t^z dz$$

$$\text{s.t.} \quad \int_0^1 G\left(\frac{Y_t^z}{Y_t}; \lambda_t^p\right) dz = 1$$

where G strictly concave and increasing and $G(1) = 1$ and λ_t^p is the net price markup, which is assumed to follow an AR(1) process with i.i.d. Normal error term: $\log(\lambda_t^p) = \left(1 - \rho_p\right) \log(\lambda^p) + \rho_p \log\left(\lambda_{t-1}^p\right) + \eta_t^p$.

From the first order conditions, we obtain:

$$Y_t^z = Y_t G'^{-1}\left[\frac{P_t^z}{P_t} \int_0^1 G'\left(\frac{Y_t^z}{Y_t}\right)\left(\frac{Y_t^z}{Y_t}\right) dz\right]$$

Intermediate good firms Intermediate firms z are monopolistically competitive and use as inputs capital and labor services, $u_t^z K_t^z$ and h_t^z respectively. Firms are subject to a payroll tax, τ_t^{wf} when using the labor input. The production technology is:

$$Y_t^z = \varepsilon_t^a [u_t^z K_t^z]^\alpha [z_t h_t^z]^{1-\alpha} - z_t \Phi$$

where Φ are fixed production costs. ε_t^a defines a transitory total factor productivity shock, evolving as an AR(1) process:

$$\varepsilon_t^a = \rho_l^a \varepsilon_{t-1}^a + \eta_t^a$$

where η_t^a is an i.i.d. Normal innovation term. The term z_t denotes a labor-augmenting technology process with permanent effects. We posit that $g_{z,t} = \frac{z_t}{z_{t-1}}$ evolves according to:

$$\log\left(g_{z,t}\right) = \left(1-\rho_{g_z}\right)\log\left(g_z\right) + \rho_{g_z}\log\left(g_{z,t-1}\right) + \eta_t^{g_z} \tag{18}$$

where $\eta_t^{g_z}$ is an i.i.d. Normal innovation term and g_z denotes a deterministic trend.

Profits maximization leads to the following:

$$\frac{u_t K_t}{h_t} = \frac{\alpha}{(1-\alpha)} \frac{\left(1+\tau_t^{wf}\right) W_t}{R_t^k} \tag{19}$$

In this framework, the capital-labour ratio is equal across firms and the marginal cost is therefore equal across firms:

$$MC_t = \alpha^{-\alpha}\left(1-\alpha\right)^{-(1-\alpha)}\left(\varepsilon_t^a\right)^{-1} z_t^{-(1-\alpha)}\left(R_t^k\right)^{\alpha}\left[\left(1+\tau_t^{wf}\right)W_t\right]^{1-\alpha} \tag{20}$$

Price setting Intermediate goods prices are sticky à la Calvo (1983). Firm z receives permission to optimally reset its price with probability $\left(1-\xi_p\right)$. Firms that cannot re-optimize adjust the price according to the following scheme:

$$P_t^z = \pi_{t-1}^{\chi_p}\bar{\pi}_t^{1-\chi_p} P_{t-1}^z$$

The representative firm chooses the optimal price $\tilde{P}_t^z$ that expected maximizes profits :

$$\max_{\tilde{P}_t^z} E_t \sum_{s=0}^{\infty} \xi_p^s \Xi_{t,t+s}\left[\frac{\tilde{P}_t^z \pi_{t,t+s-1}^{\chi_p}\bar{\pi}_{t,t+s}^{1-\chi_p}}{P_{t+s}} Y_{t+s}^z - \frac{MC_{t+s}}{P_{t+s}} Y_{t+s}^z\right]$$

subject to

$$Y_{t+s}^z = G'^{-1}\left(\frac{\tilde{P}_t^z \pi_{t,t+s-1}^{\chi_p}\bar{\pi}_{t,t+s}^{1-\chi_p}}{P_{t+s}} \int_0^1 G'\left(\frac{Y_{t+s}^z}{Y_{t+s}}\right)\frac{Y_{t+s}^z}{Y_{t+s}} dz\right) Y_{t+s}$$

where MC_t is the nominal marginal cost and $\Xi_{t,t+s}$ is the stochastic discount factor for real payoffs:

$$\Xi_{t,t+s} = \varepsilon^b_{t+s}\beta^s \frac{\Lambda^o_{t+s}}{\Lambda^o_t}$$

Following Smets and Wouters (2007), we define $\omega_t = \frac{\tilde{P}^z_t}{P_t}\int_0^1 G'\left(\frac{Y^z_t}{Y_t}\right)\frac{Y^z_t}{Y_t}dz$ and $x_t = G'^{-1}(\omega_t)$, hence the first order condition is:

$$E_t \sum_{s=0}^{\infty} \xi_p^s \frac{\Xi_{t,t+s}}{P_{t+s}} Y^z_{t+s}\left[\tilde{P}^z_t \pi^{\chi_p}_{t,t+s-1}\bar{\pi}^{1-\chi_p}_{t,t+s} + \left(\tilde{P}^z_t \pi^{\chi_p}_{t,t+s-1}\bar{\pi}^{1-\chi_p}_{t,t+s} - MC_{t+s}\right)\frac{1}{G'^{-1}(\omega_{t+s})}\frac{G'(x_{t+s})}{G''(x_{t+s})}\right] = 0$$

The aggregate price index dynamic equation is:

$$\begin{aligned} P_t &= \left(1-\xi_p\right)\tilde{P}^z_t G'^{-1}\left(\frac{\tilde{P}^z_t\int_0^1 G'\left(\frac{Y^z_{t+s}}{Y_{t+s}}\right)\frac{Y^z_{t+s}}{Y_{t+s}}dz}{P_t}\right) \\ &\quad +\xi_p \pi^{\chi_p}_{t-1}\bar{\pi}_t^{1-\chi_p} P_{t-1} G'^{-1}\left(\frac{\pi^{\chi_p}_{t-1}\bar{\pi}_t^{1-\chi_p}P_{t-1}\int_0^1 G'\left(\frac{Y^z_{t+s}}{Y_{t+s}}\right)\frac{Y^z_{t+s}}{Y_{t+s}}dz}{P_t}\right) \end{aligned}$$

5.1.5 Government budget constraint

The government budget constraint in nominal terms is:

$$\begin{aligned} & P_t G_t + R_{t-1}B_t + TR_t = \\ = \;& B_{t+1} + \tau^c_t P_t C_t + \left(\tau^l_t + \tau^{wh}_t + \tau^{wf}_t\right) W_t h_t + \tau^k_t \left[R^k_t u_t - \left(a\left(u_t\right)+\delta\right)P_t\right] K_t + T_t \end{aligned}$$

5.1.6 Aggregation

The relationship between aggregate and individual variables is:[20]

$$C_t = \theta C_t^{rt} + (1-\theta)\, C_t^o$$

$$K_t = (1-\theta)\, K_t^o$$

$$I_t = (1-\theta)\, I_t^o$$

$$B_t = (1-\theta)\, B_t^o$$

$$d_t = (1-\theta)\, d_t^o$$

$$T_t = (1-\theta)\, T_t^o$$

$$TR_t = \theta TR_t^{rt} + (1-\theta)\, TR_t^o$$

5.1.7 Market clearing

The aggregate resource constraint:

$$Y_t = C_t + G_t + I_t + a\,(u_t)\, K_t$$

Labor market clearing:

$$\begin{aligned} h_t &= \int_0^1 h_t^j dj \\ &= h_t^d \int_0^1 \left(\frac{W_t^j}{W_t} \right)^{-\frac{1+\lambda_t^w}{\lambda_t^w}} dj \\ &= s_{W,t} h_t^d \end{aligned}$$

[20] Aggregate and average variables here coincide. For this reason, wealth holdings of Ricardian households are larger than the corresponding aggregates.

where $s_{W,t} = \int_0^1 \left(\frac{W_t^j}{W_t}\right)^{-\frac{1+\lambda_t^w}{\lambda_t^w}} dj$ is the wage dispersion across the differentiated labor services.

Capital market:

$$u_t K_t = u_t \int_0^1 K_t^z dz$$

Firms' aggregate demand for labor input:

$$h_t^d = \int_0^1 h_t^z dz$$

Good market:

$$\int_0^1 Y_t^z dz = \int_0^1 \left(\frac{P_t^z}{P_t}\right)^{-\frac{1+\lambda_t^p}{\lambda_t^p}} dz Y_t = s_{P,t} Y_t$$

where $s_{P,t} = \int_0^1 \left(\frac{P_t^z}{P_t}\right)^{-\frac{1+\lambda_t^p}{\lambda_t^p}} dz$ is the price dispersion across differentiated goods.

Note that both $s_{W,t}$ and $s_{P,t}$ vanish in the log-linearized version of the model.

5.2 Non-linear equations for growth-adjusted variables

After deriving the first order conditions for Ricardian agents, unions and firms, we adjust all growing variables for growth to obtain a stationary equilibrium. In this case, lower case letters stand for "adjusted" variables, for example, $y_t = \frac{Y_t}{z_t}$. Notice that $w_t = \frac{W_t}{P_t z_t}$ and $\lambda_t^o = \Lambda_t^o z_t$. We end up with the following set of non linear equations:

$$(c_t^o)^{-\sigma} c_{t-1}^{b(\sigma-1)} \exp\left(\frac{(\sigma-1)\,\varepsilon_t^l}{1+\phi_l} (h_t^o)^{1+\phi_l}\right) = \lambda_t^o (1+\tau_t^c) \tag{21}$$

$$R_t = \pi_{t+1} g_{z,t+1} \frac{\lambda_t^o}{\beta \varepsilon_t^b \lambda_{t+1}^o} \tag{22}$$

$$\begin{aligned} 1 &= Q_t^o \varepsilon_t^i \left\{ 1 - \gamma_I \left(g_{z,t} \frac{i_t}{i_{t-1}} - g_z \right) g_{z,t} \frac{i_t}{i_{t-1}} - \frac{\gamma_I}{2} \left(g_{z,t} \frac{i_t}{i_{t-1}} - g_z \right)^2 \right\} \\ &+ \frac{1}{g_{z,t+1}} \frac{\lambda_{t+1}^o}{\lambda_t^o} Q_{t+1}^o \varepsilon_{t+1}^i \beta \gamma_I \left(g_{z,t+1} \frac{i_{t+1}}{i_t} - g_z \right) \left(\frac{i_{t+1}}{i_t} \right)^2 \end{aligned} \tag{23}$$

$$\frac{1}{g_{z,t+1}} \frac{\lambda_{t+1}^o}{\lambda_t^o} \beta \left\{ \left(1 - \tau_{t+1}^k\right) \left[r_{t+1}^k u_{t+1} - a\left(u_{t+1}\right) \right] + \tau_{t+1}^k \delta + Q_{t+1}^o \left(1 - \delta\right) \right\} = Q_t^o \tag{24}$$

$$r_t^k = \gamma_{u1} + \gamma_{u2} \left(u_t - 1\right) \tag{25}$$

$$k_{t+1} = \left(1 - \delta\right) \frac{k_t}{g_{z,t}} + \varepsilon_t^i \left[1 - \frac{\gamma_I}{2} \left(g_{z,t} \frac{i_t}{i_{t-1}} - g_z \right)^2 \right] i_t \tag{26}$$

$$\left(1 + \tau_t^c\right) c_t^{rt} = \left(1 - \tau_t^l - \tau_t^{wh}\right) w_t h_t + tr_t^{rt} \tag{27}$$

$$g_t + \frac{R_{t-1}}{\pi_t} \frac{b_t}{g_{z,t}} + tr_t = \left\{ \begin{array}{c} b_{t+1} + \tau_t^c c_t + \left(\tau_t^l + \tau_t^{wh} + \tau_t^{wf} \right) w_t h_t + \\ + \tau_t^k \left[r_t^k u_t - \left(a\left(u_t\right) + \delta \right) \right] \frac{k_t}{g_{z,t}} + t_t \end{array} \right\} \tag{28}$$

$$y_t = c_t + g_t + i_t + \frac{a\left(u_t\right) k_t}{g_{z,t}} \tag{29}$$

$$c_t = \theta c_t^{rt} + \left(1 - \theta\right) c_t^o \tag{30}$$

$$
\begin{aligned}
0 \;\; = \;\; & E_t \sum_{s=0}^{\infty} (\xi_w \beta)^s \, c_{t+s-1}^{b(\sigma-1)} \exp\left(\frac{(\sigma-1)\,\varepsilon_{t+s}^l}{1+\phi_l} (h_{t+s})^{1+\phi_l} \right) \left(\tilde{w}_t^j\right)^{-\frac{1+\lambda_{t+s}^w}{\lambda_{t+s}^w}} \left(\frac{\pi_{t,t+s-1}^{\chi_w} \bar{\pi}_{t,t+s}^{1-\chi_w}}{w_{t+s}\pi_{t,t+s}} \right)^{-\frac{1+\lambda_{t+s}^w}{\lambda_{t+s}^w}} h_{t+s}^d \cdot \\
& \cdot \left\{ \begin{array}{c} \tilde{w}_t^j \frac{\left(1-\tau_{t+s}^l-\tau_{t+s}^{wh}\right)\pi_{t,t+s-1}^{\chi_w}\bar{\pi}_{t,t+s}^{1-\chi_w}}{\left(1+\tau_{t+s}^c\right)\pi_{t,t+s}} \left(1-\frac{1+\lambda_{t+s}^w}{\lambda_{t+s}^w}\right) \left[(1-\theta)\left(c_{t+s}^o\right)^{-\sigma} + \theta\left(c_{t+s}^{rt}\right)^{-\sigma}\right] \\ +\frac{1+\lambda_{t+s}^w}{\lambda_{t+s}^w} \left[(1-\theta)\left(c_{t+s}^o\right)^{-\sigma} MRS_{t+s}^o + \theta\left(c_{t+s}^{rt}\right)^{-\sigma} MRS_{t+s}^{rt}\right] \end{array} \right\}
\end{aligned} \tag{31}
$$

$$
w_t = \left[\xi_w \left(\frac{\pi_{t-1}^{\chi_w}\bar{\pi}_t^{1-\chi_w}}{\pi_t} w_{t-1} \right)^{\frac{1}{\lambda_t^w}} + (1-\xi_w)\left(\tilde{w}_t\right)^{\frac{1}{\lambda_t^w}} \right]^{\lambda_t^w} \tag{32}
$$

$$
\frac{u_t k_t}{h_t g_{z,t}} = \frac{\alpha}{(1-\alpha)} \frac{\left(1+\tau_t^{wf}\right) w_t}{r_t^k} \tag{33}
$$

$$
mc_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} \left(\varepsilon_t^a\right)^{-1} \left(r_t^k\right)^{\alpha} \left[\left(1+\tau_t^{wf}\right) w_t\right]^{1-\alpha} \tag{34}
$$

$$
s_{P,t} y_t = \varepsilon_t^a \left(u_t \frac{k_t}{g_{z,t}} \right)^{\alpha} \left(h_t^d\right)^{1-\alpha} - \Phi \tag{35}
$$

$$
E_t \sum_{s=0}^{\infty} \left(\xi_p \beta\right)^s \varepsilon_t^b \frac{\lambda_{t+s}^o}{\lambda_t^o} y_{t+s}^z \left[\begin{array}{c} \tilde{p}_t^z \frac{\pi_{t,t+s-1}^{\chi_p}\bar{\pi}_{t,t+s}^{1-\chi_p}}{\pi_{t,t+s}} \left(1+\frac{1}{G'^{-1}(\omega_{t+s})}\frac{G'(x_{t+s})}{G''(x_{t+s})}\right) + \\ -mc_{t+s}\frac{1}{G'^{-1}(\omega_{t+s})}\frac{G'(x_{t+s})}{G''(x_{t+s})} \end{array} \right] = 0 \tag{36}
$$

$$
\begin{aligned}
1 \;\; = \;\; & \left(1-\xi_p\right) \tilde{p}_t^z G'^{-1} \left(\tilde{p}_t^z \int_0^1 G'\left(\frac{y_t^z}{y_t}\right) \frac{y_t^z}{y_t} dz \right) \\
& + \xi_p \pi_{t-1}^{\chi_p} \bar{\pi}_t^{1-\chi_p} \pi_t^{-1} G'^{-1} \left(\pi_{t-1}^{\chi_p} \bar{\pi}_t^{1-\chi_p} \pi_t^{-1} \int_0^1 G'\left(\frac{y_t^z}{y_t}\right) \frac{y_t^z}{y_t} dz \right)
\end{aligned} \tag{37}
$$

$$
tr_t = \theta tr_t^{rt} + (1-\theta)\, tr_t^o \tag{38}
$$

$$h_t = s_{W,t} h_t^d \tag{39}$$

$$s_{W,t} = \int_0^1 \left(\frac{W_t^j}{W_t} \right)^{-\frac{1+\lambda_t^w}{\lambda_t^w}} dj \tag{40}$$

$$s_{P,t} = \int_0^1 \left(\frac{P_t^z}{P_t} \right)^{-\frac{1+\lambda_t^p}{\lambda_t^p}} dz \tag{41}$$

$$MRS_t^o = c_t^o h_t^{\phi_l} \tag{42}$$

$$MRS_t^{rt} = c_t^{rt} h_t^{\phi_l} \tag{43}$$

5.2.1 Log-linearized equations

After log-linearizing the model around its non-stochastic steady state and making some algebra, we obtain the following set of equations. Hatted variables stand for variables in log deviation from their steady state, for example: $\hat{y}_t = \log\left(\frac{y_t}{y}\right)$. Notice also that fiscal variables, such as government spending, have been defined in deviation from steady state output, for example: $\hat{g}_t = \frac{g_t - g}{y}$.

$$\begin{aligned} \hat{c}_t^o &= \hat{c}_{t+1}^o + \frac{(1-\sigma)\, b}{\sigma} \left(\hat{c}_t - \hat{c}_{t-1} \right) - \frac{1}{\sigma} \left(\hat{\varepsilon}_t^b + \hat{R}_t - \hat{\pi}_{t+1} - \hat{g}_{z,t+1} \right) \\ &\quad + \frac{(1-\sigma)\, h^{1+\phi_l}}{\sigma} \left(\hat{h}_{t+1} - \hat{h}_t \right) + \frac{1}{\sigma} \frac{\tau^c}{1+\tau^c} \left(\hat{\tau}_{t+1}^c - \hat{\tau}_t^c \right) \end{aligned} \tag{44}$$

$$\begin{aligned} \hat{\imath}_t &= \frac{1}{\gamma_I g_z^2 (1+\beta)} \left(\hat{Q}_t^o + \hat{\varepsilon}_t^i \right) - \frac{1}{1+\beta} \hat{g}_{z,t} + \frac{1}{1+\beta} \hat{\imath}_{t-1} \\ &\quad + \frac{\beta}{1+\beta} \hat{\imath}_{t+1} + \frac{\beta}{1+\beta} \hat{g}_{z,t+1} \end{aligned} \tag{45}$$

$$
\begin{aligned}
&-\hat{R}_t - \hat{\varepsilon}_t^b + \hat{\pi}_{t+1} + \frac{\beta}{g_z}\left(1-\tau^k\right) r^k \hat{r}_{t+1}^k \\
&+\frac{\beta}{g_z}(1-\delta)\hat{Q}_{t+1}^o + \frac{\beta}{g_z}\left(\delta - r^k\right)\tau^k \hat{\tau}_{t+1}^k = \hat{Q}_t^o
\end{aligned} \tag{46}
$$

$$
\hat{r}_t^k = \frac{\gamma_{u2}}{r^k}\hat{u}_t = \frac{\sigma_u}{1-\sigma_u}\hat{u}_t \tag{47}
$$

$$
\hat{k}_{t+1} = \frac{(1-\delta)}{g_z}\hat{k}_t + \frac{i}{k}\hat{\imath}_t - \frac{(1-\delta)}{g_z}\hat{g}_{z,t} + \frac{i}{k}\hat{\varepsilon}_t^i \tag{48}
$$

$$
(1+\tau^c)\frac{c^{rt}}{c}\hat{c}_t^{rt} + \frac{c^{rt}}{c}\tau^c\hat{\tau}_t^c + w^{rt}h\left(\tau^l\hat{\tau}_t^l + \tau^{wh}\hat{\tau}_t^{wh}\right) \tag{49}
$$

$$
= \left(1-\tau^l-\tau^{wh}\right)\frac{wh}{c}\left(\hat{w}_t + \hat{h}_t\right) + \frac{y}{c}\widehat{tr}_t^{rt} \tag{50}
$$

$$
0 = \frac{c}{y}\hat{c}_t + \hat{g}_t + \frac{i}{y}\hat{\imath}_t - \hat{y}_t + \frac{\gamma_{u1}k}{yg_z}\hat{u}_t \tag{51}
$$

$$
\hat{c}_t = \theta\frac{c^{rt}}{c}\hat{c}_t^{rt} + (1-\theta)\frac{c^o}{c}\hat{c}_t^o \tag{52}
$$

$$
\begin{aligned}
\left(1+\beta\chi_p\right)\hat{\pi}_t &= \chi_p\hat{\pi}_{t-1} + \beta\hat{\pi}_{t+1} - \beta\left(1-\chi_p\right)\hat{\bar{\pi}}_{t+1} + \left(1-\chi_p\right)\hat{\bar{\pi}}_t \\
&\quad + A\frac{\left(1-\beta\xi_p\right)\left(1-\xi_p\right)}{\xi_p}\left(\widehat{mc}_t + \hat{\lambda}_t^p\right)
\end{aligned} \tag{53}
$$

$$
\begin{aligned}
&\hat{w}_t = -\frac{(1-\xi_w)(1-\xi_w\beta)}{(1+\beta)\xi_w}\hat{w}_t + \frac{(1-\xi_w)(1-\xi_w\beta)}{(1+\beta)\xi_w}\frac{\lambda^w}{1+\lambda^w}\hat{\lambda}_t^w \\
&+\frac{(1-\xi_w)(1-\xi_w\beta)\tau^c}{(1+\beta)\xi_w(1+\tau^c)}\hat{\tau}_t^c + \frac{(1-\xi_w)(1-\xi_w\beta)\tau^l}{(1+\beta)\xi_w(1-\tau^l-\tau^{wh})}\hat{\tau}_t^l + \frac{(1-\xi_w)(1-\xi_w\beta)\tau^{wh}}{(1+\beta)\xi_w(1-\tau^l-\tau^{wh})}\hat{\tau}_t^{wh} \qquad (54) \\
&+\frac{(1-\xi_w)(1-\xi_w\beta)}{(1+\beta)\xi_w(\varpi+1)}\left\{\left[\frac{\sigma\varrho\left(\frac{c^{rt}}{c^o}-1\right)}{(\varrho+1)}+1\right]\widehat{MRS}_t^o + \left[\varpi - \frac{\sigma\varrho\left(\frac{c^{rt}}{c^o}-1\right)}{(\varrho+1)}\right]\widehat{MRS}_t^{rt}\right\} \qquad (55) \\
&+\frac{\beta}{1+\beta}\hat{w}_{t+1} + \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{\chi_w}{1+\beta}\hat{\pi}_{t-1} - \frac{(1+\beta\chi_w)}{1+\beta}\hat{\pi}_t + \frac{\beta}{1+\beta}\hat{\pi}_{t+1} + \frac{(1-\chi_w)}{1+\beta}\hat{\bar{\pi}}_t - \frac{\beta}{1+\beta}(1-\chi_w)\hat{\bar{\pi}}_{t+1}
\end{aligned}
$$

$$\widehat{MRS}_t^o = \hat{c}_t^o + \phi_l \hat{h}_t \tag{56}$$

$$\widehat{MRS}_t^{rt} = \hat{c}_t^{rt} + \phi_l \hat{h}_t \tag{57}$$

$$\hat{u}_t + \hat{k}_t - \hat{h}_t - \hat{g}_{z,t} = \hat{w}_t - \hat{r}_t^k + \frac{\tau^{wf}}{1+\tau^{wf}} \hat{\tau}_t^{wf} \tag{58}$$

$$\widehat{mc}_t = -\hat{\varepsilon}_t^a + \alpha \hat{r}_t^k + (1-\alpha)\,\hat{w}_t + (1-\alpha)\,\frac{\tau^{wf}}{1+\tau^{wf}} \hat{\tau}_t^{wf} \tag{59}$$

$$\hat{y}_t = \frac{y+\Phi}{y}\hat{\varepsilon}_t^a + \frac{\alpha\,(y+\Phi)}{y}\hat{k}_t + \frac{\alpha\,(y+\Phi)}{y}\hat{u}_t + \frac{(1-\alpha)\,(y+\Phi)}{y}\hat{h}_t - \alpha\frac{y+\Phi}{y}\hat{g}_{z,t} \tag{60}$$

$$\hat{R}_t = \phi_R \hat{R}_{t-1} + (1-\phi_R)\left(\hat{\overline{\pi}}_t + \phi_\pi\left(\hat{\pi}_{t-1} - \hat{\overline{\pi}}_t\right) + \phi_y \hat{y}_t\right) + \phi_{\Delta\pi}\left(\hat{\pi}_t - \hat{\pi}_{t-1}\right) + \phi_{\Delta y}\left(\hat{y}_t - \hat{y}_{t-1}\right) + \hat{\varepsilon}_t^r \tag{61}$$

$$\begin{aligned} & \hat{g}_t + \frac{b}{y}\frac{R}{\pi g_z}\hat{R}_{t-1} + \frac{R}{\pi g_z}\hat{b}_t - \frac{b}{y}\frac{R}{\pi g_z}\hat{g}_{z,t} - \frac{b}{y}\frac{R}{\pi g_z}\hat{\pi}_t + \widehat{tr}_t - \hat{t}_t \\ = \; & \hat{b}_{t+1} + \frac{c}{y}\tau^c\left(\hat{\tau}_t^c + \hat{c}_t\right) \\ & + \frac{wh}{c}\frac{c}{y}\left[\tau^l\hat{\tau}_t^l + \tau^{wh}\hat{\tau}_t^{wh} + \tau^{wf}\hat{\tau}_t^{wf} + \left(\tau^l + \tau^{wh} + \tau^{wf}\right)\left(\hat{w}_t + \hat{h}_t\right)\right] \\ & + \frac{k}{y}\frac{\tau^k}{g_z}\left[r^k\hat{r}_t^k + \left(r^k - \gamma_{u1}\right)\hat{u}_t + \left(r^k - \delta\right)\left(\hat{\tau}_t^k + \hat{k}_t - \hat{g}_{z,t}\right)\right] \end{aligned} \tag{62}$$

$$\widehat{tr}_t = \theta \widehat{tr}_t^{rt} + (1-\theta)\,\widehat{tr}_t^o \tag{63}$$

$$\hat{e}_t = \frac{\beta}{1+\beta}E_t\hat{e}_{t+1} + \frac{1}{1+\beta}\hat{e}_{t-1} + \frac{(1-\xi_e)\,(1-\beta\xi_e)}{(1+\beta)\,\xi_e}\left(\hat{h}_t - \hat{e}_t\right) \tag{64}$$

with $A = \frac{\left(1+\frac{G''(x)}{G'(x)}\right)}{\left(2+\frac{G'''(x)}{G''(x)}\right)} = \frac{1}{\lambda^p\alpha^p+1}$ (where λ^p is steady state price markup and α^p is the steady state elasticity of substitution between goods), $\varrho = \frac{\theta}{1-\theta}\left(\frac{c^{rt}}{c^o}\right)^{-\sigma}$ and $\varpi = \varrho\frac{c^{rt}}{c^o}$.

The estimated structural shocks (not including fiscal shocks) are:

$$\hat{\varepsilon}_t^a = \rho_a \hat{\varepsilon}_{t-1}^a + \eta_t^a$$

$$\hat{\varepsilon}_t^i = \rho_i \hat{\varepsilon}_{t-1}^i + \eta_t^i$$

$$\hat{\varepsilon}_t^r = \rho_r \hat{\varepsilon}_{t-1}^r + \eta_t^r$$

$$\hat{\lambda}_t^p = \rho_p \hat{\lambda}_{t-1}^p + \eta_t^p$$

$$\hat{\lambda}_t^w = \rho_w \hat{\lambda}_{t-1}^w + \eta_t^w$$

$$\hat{\varepsilon}_t^b = \rho_b \hat{\varepsilon}_{t-1}^b + \eta_t^b$$

$$\hat{g}_{z,t} = \rho_{g_z} \hat{g}_{z,t-1} + \eta_t^{g_z}$$